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June 30, 1969

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HYBRID MISSION EFFECTS ON THE LOI
PHASE OF THE APOLLO 11 (MISSION G)
ABORT PLAN

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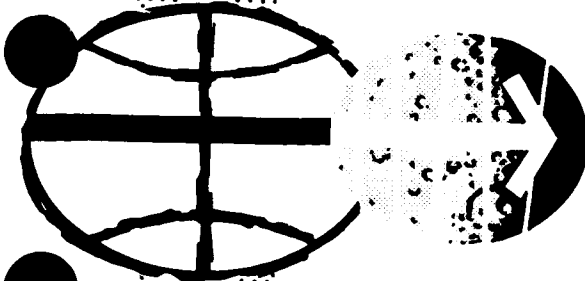
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TO : See attached list

DATE: JUN 26 1969

File No. 69-FM13-358

FROM : FM13/Chief, Mission Planning Support Office

SUBJECT: Hybrid mission effects on the Apollo 11 LOI Abort Plan

The Apollo 11 Operational Abort Plan was published in MSC I.N. 69-FM-167, and the launch window effects on this plan were published in MSC I.N. 69-FM-172. The attached document supplements these previous documents by providing the hybrid mission effects on the LOI aborts.

The hybrid mission is always constrained within the DPS capability to provide earth return during translunar coast. However, a gap does exist during the LOI burn for which the DPS could not provide the ΔV for earth return. This gap is well defined in the attached document. Furthermore, the APS capability to make up the ΔV is investigated. The feasibility of actually performing a docked APS burn under these conditions is being investigated by ASPO, GAEC, FCD and FCOD.

The hybrid effects for LOI are shown for two typical Apollo 11 hybrid mission launch dates, July 21 and September 13. Recently, the Apollo 11 July launch window configuration was redefined coupled with a built-in midcourse during translunar coast in order to delay the arrival time at the moon. This causes the July 18 missions to also be hybrid. Therefore, the enclosed data are typically applicable for a July 18 launch.

R. P. Parten

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Enclosure

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MSC INTERNAL NOTE NO. 69-FM-178

PROJECT APOLLO

HYBRID MISSION EFFECTS ON THE LOI PHASE
OF THE APOLLO 11 (MISSION G) ABORT PLAN

By Charles E. Foggatt and Dallas G. Ives
Flight Analysis Branch

June 30, 1969

MISSION PLANNING AND ANALYSIS DIVISION
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HYBRID MISSION EFFECTS ON THE LOI PHASE OF THE

APOLLO 11 (MISSION G) ABORT PLAN

By Charles E. Foggatt and Dallas G. Ives

1.0 SUMMARY

The effects on the LOI abort requirements caused by the use of a hybrid translunar trajectory are discussed. The net result is that the complete DPS backup that exists for a free-return mission does not necessarily exist for a hybrid mission. A region possibly as large as 1 minute may occur during the LOI burn during which the DPS does not have the capability to return the spacecraft to earth after an SPS failure. (The nominal LOI burn time is approximately 6 min.) For this region of burn time, additional procedures which use both the DPS and APS engines are considered which provide the necessary ΔV to abort.

In addition, parametric abort data are included for two launch days (July 21, 1969, and September 13, 1969), and the variation in the LOI abort requirements throughout a typical daily launch window when launch is delayed is shown.

2.0 INTRODUCTION

In the operational abort plan for Apollo 11 (Mission G) (ref. 1), the abort procedures and supporting parametric data were presented for all phases of a lunar landing mission, excluding aborts during lunar landing operations. The data were based on a nominal July 16, 1969, launch date with a 72° launch azimuth and TLI planned for the first opportunity. The changes to the abort data for aborts which occurred later in the Apollo 11 (Mission G) launch window were documented in the launch window effects document (ref. 2).

The primary change in abort data throughout the Apollo 11 (Mission G) launch window is caused by a requirement for a hybrid lunar mission if launch occurs July 21 or later. A complete description of the hybrid mission rationale is not included in this document, but it suffices to say that the resultant translunar trajectory, unlike free-return trajectories, requires a substantial thrust maneuver to return the spacecraft to earth in the event LOI is not performed.

The most significant change in the abort capability caused by the inclusion of the hybrid mission occurs in the LOI abort phase. In this document, the reasons are discussed for the significant changes in the LOI abort requirements which were briefly mentioned in reference 2, and pertinent data are presented for two specific launch days (July 21, 1969, and September 13, 1969). Finally, the changes in LOI abort requirements as launch is delayed during the daily launch window are discussed.

This document and its relation to other Apollo 11 (Mission G) milestones for the Contingency Analysis Section are shown in appendix A.

3.0 SYMBOLS

AOL	Atlantic Ocean line (recovery)
APS	ascent propulsion subsystem
CSM	command and service modules
DPS	descent propulsion subsystem
DVM	LOI ΔV magnitude
FCUA	fuel-critical unspecified area
g.e.t.	ground elapsed time
GETL	ground elapsed time of landing
LM	lunar module
LOI	lunar orbit insertion
MPL	mid-Pacific line (recovery)
RCS	reaction control subsystem
REFSMMAT	transformation matrix from inertial to stable member
SM	service module
SPS	service propulsion subsystem
TAZ	time from abort to landing

TEI	transearth injection
TLI	translunar injection
t_D	delay time to abort
ΔV	delta velocity
ΔV_1	ΔV of mode II corrective maneuver

4.0 ABORTS DURING LOI

4.1 Characteristics of Trajectories That Result From Premature LOI Shutdown

The discussion in reference 1 of the classes of trajectories after an SPS failure during LOI applies here. The actual burn times for each class of trajectory is a function of the launch date, but they are approximately as follows.

1. Hyperbola: LOI-1 ignition to LOI-1 ignition plus 2 minutes
2. Unstable ellipse: LOI-1 ignition plus 2 minutes to LOI-1 ignition plus 3 minutes
3. Stable ellipse: LOI-1 ignition plus 3 minutes to LOI-2 shutdown

One important difference that should be noted here is that the initial hyperbola of class 1 (burn time = 0 sec) is no longer a free-return trajectory but requires a substantial ΔV to return to earth. As will be shown in subsequent sections, this initial ΔV is important because it can be used to estimate LOI abort capability.

4.2 General Abort Modes

Lunar phase abort maneuvers for Apollo 11 Mission G are of three basic types.

1. Mode I - a one-impulse maneuver that returns the spacecraft directly to earth. The burn is initiated as soon as possible after LOI termination to reduce the necessary ΔV . The applicable preabort trajectory class is the hyperbolic region (fig. 1).

2. Mode II - a two-impulse maneuver that necessitates one intermediate lunar orbit. The first impulse is directed down the radius vector and is initiated as soon as possible after LOI termination. The burn reduces the orbital period and provides a stable intermediate orbit. The second burn occurs near perilune and injects the spacecraft on the transearth trajectory (fig. 2).

3. Mode III - a one-impulse maneuver initiated near perilune after one or more orbits (similar to the normal TEI burn). This mode is used when class III (stable ellipse) trajectories occur. By definition, the preabort period is less than 15 hours (fig. 3).

Although the normal abort modes of the preceding paragraphs are sufficient to provide a complete abort capability for the nominal July 16 (free-return) mission, it will be seen that additional procedures are required for typical hybrid missions.

The most acceptable procedure considered here involves use of both the DPS and APS engines in the docked configuration to provide the necessary ΔV . Thus, mode I is modified to include a DPS burn to depletion followed by descent stage jettison and an APS burn. The mode II second burn is similarly modified. A more extreme abort procedure is discussed in appendix B. The procedure consists of an SM jettison and initiation of a docked DPS burn for a fast earth return.

The operational feasibility of the two additional abort procedures is beyond the scope of this document. However, because an SPS failure in the critical region could be catastrophic unless additional abort capability is provided, data for both procedures are included.

4.3 Comparison of Hybrid and Free-Return LOI Abort Capability

The DPS abort backup for SPS failures during LOI is significantly affected by the pre-LOI trajectory characteristics. The hybrid translunar trajectory results in a lower energy hyperbola than its free-return counterpart. Because the spacecraft has a lower velocity at any point than a free-return trajectory, a higher ΔV must be applied to inject it into a satisfactory transearth coast. In addition, the initial lunar hyperbola (LOI burn = 0 sec) is oriented in a clockwise direction several degrees from the free-return hyperbola when viewed from the north. This orientation is undesirable from the abort standpoint because it increases the required abort ΔV .

The increase in the abort requirements can best be illustrated by a comparison of the fuel-critical abort ΔV 's for a typical free-return

and a hybrid lunar mission. The FCUA abort solutions for the nominal July 16, 1969, free-return lunar mission are shown in figure 4(a). For this mission, a DPS backup exists throughout the LOI burn. Similar data for a July 21, 1969, hybrid mission are shown in figure 4(b).

Two basic differences in the figures are the following.

a. The mode I ΔV required begins at 930 fps for the hybrid ($t_D = 2$ hr) compared to 0 fps for the free-return case. Because the slope of the ΔV curves are very similar, the hybrid mode I abort capability ends at 1^m10^s compared to 1^m57^s for the free-return case.

b. Because of the undesirable orientation of the hybrid premature shutdown trajectories, the mode II abort capability begins at 1^m56^s for the hybrid mission while the free-return case begins at 1^m38^s . In addition, the ΔV reserves for the mode II and mode III regions are much smaller for the hybrid mission than they are for the free-return case.

The net result is that the mode I/mode II overlap which is available for the nominal July 16, 1969, mission (ref. 1) does not exist for this typical hybrid mission (July 21, 1969). In fact, a region of 48 seconds appears in which neither DPS abort is possible. Note that this gap region is a function of the specific hybrid trajectory chosen and may be estimated once the abort ΔV for a no-LOI-burn case is established. This situation will be illustrated in subsequent sections.

4.4 Abort Capability for Nominal July 21, 1969, Hybrid Lunar Mission (72° azimuth, first opportunity)

The first day in the Apollo 11 (Mission G) launch window when a hybrid lunar mission is planned is July 21, 1969. In this section, the abort capability available when the normal LOI abort modes are used is summarized, and the capability of the DPS/APS abort procedures mentioned in section 4.2 is discussed.

The instantaneous conic parameters during the LOI burn for a July 21, 1969 launch are shown in figure 5. From the figure, it can be determined that the mode III region (class 3 trajectories) begins at 2^m40^s into the burn when the preabort orbital period is 15 hours. At this orbital period, a stable lunar ellipse is established. The LOI ΔV magnitude is shown in figure 6 as a function of SPS burn time.

The FCUA abort ΔV requirements for the entire LOI burn are summarized in figure 4(b). In addition to the DPS ΔV available, the total DPS/APS ΔV is shown in the figure. As mentioned in section 4.3, a gap of 48 seconds exists where the DPS ΔV is exceeded, and additional ΔV is required. In this region, the DPS/APS abort procedure discussed in section 4.2 could be initiated to provide a successful abort. Although the mode I region could be extended to an LOI burn of 1^m48^s (with all available APS propellant being used) before a mode II abort is required, the highest APS ΔV actually needed is 400 fps or 4^m10^s of APS burn duration. The need for the highest APS ΔV occurs at 1^m30^s into the LOI burn when the mode I and mode II lines cross.

The abort ΔV required for returns to the MPL for all three modes of abort is summarized in figure 7. Although MPL returns are possible throughout the burn when the APS ΔV is available, comparison of figures 4(b) and 7 shows that a much larger APS ΔV is required for an MPL return than for FCUA returns. In figure 8, the GETL's for the FCUA mode I and mode II aborts of figure 4(b) are shown. The GETL at the MPL and AOL are indicated in the figure. Although an MPL return would be preferred, the figure can be used to estimate an alternate landing area closer to the FCUA return point if abort ΔV is to be minimized.

The characteristics of the mode II abort required for a July 21, 1969, mission are shown in figures 9(a) through 9(d). The corrective burn ΔV magnitude is shown in figure 9(a) as a function of LOI burn time. Note that FCUA mode II aborts prior to 1^m58^s would require an APS burn after a second DPS burn which used the remaining DPS propellant. Although the mode II first burn is nominally at LOI ignition plus 2 hours, the maximum allowable time to delay abort ignition is shown in figure 9(b). For delays later than this maximum time, a perilune altitude of less than 40 n. mi. would result in the intermediate ellipse if the nominal ΔV_1 were applied. However, if a higher ΔV_1 were used, an acceptable perilune could result; although the total mode II ΔV would be increased. The time from the corrective maneuver to perilune and the perilune altitude of the intermediate ellipse are shown in figures 9(c) and 9(d), respectively. Data are shown for a corrective maneuver initiated at 2 hours and at 5 hours past LOI ignition. It can be seen that the time to perilune is slightly affected as the abort is delayed, but the primary effect is a reduction in perilune altitude.

The mode I abort and mode II corrective maneuver ignition times are determined by LM activation times because an early burn is desirable.

However, the mode II second DPS burn and Mode III abort ignition time are determined by the period of the lunar orbit achieved and are shown in figure 10.

To summarize the LOI abort capability for a July 21, 1969, hybrid lunar mission from a ΔV standpoint, the LM propulsion systems have the performance capability to return the spacecraft to earth for an SPS failure anywhere in the LOI burn. However, the DPS cannot provide the necessary ΔV in a region from 1^m10^s to 1^m58^s in the burn. It has been shown that the APS has the additional ΔV capability required to abort in this critical region of the burn.

To reiterate the discussion of section 4.2, the operational feasibility of the DPS/APS abort procedure has not been established to date because control problems may occur during the APS burn. However, a CSM/LM APS burn has been successfully simulated, and procedures are being formulated. The abort capability possible when the more extreme abort procedure discussed in section 4.2 is used (namely SM jettison) is discussed in appendix B. For both of the alternate abort procedures, certain problems exist. However, because an SPS failure could be catastrophic in the critical region of the LOI burn unless additional capability is provided, data for both procedures are included.

4.5 Variation of Abort Capability Throughout July 21, 1969, Launch Window

The variation in abort requirements during LOI, as launch is delayed during a typical daily launch window is briefly described in this section. The discussion is limited to the mode I and mode II abort requirements because the gap region between the modes is of primary importance. The mode III abort ΔV is well below the DPS ΔV available; therefore, its slight variation is not included.

The mode I and mode II abort ΔV for 72° and 108° launch azimuths for both opportunities are presented in figures 11(a) and 11(b). The mode II solutions are based on the nominal ΔV_1 curve shown in figure 9(a). The resultant times to perilune and perilune altitude of the intermediate ellipses are shown in figure 11(c) and 11(d). The net result is a very small variation in abort ΔV which does not significantly change the applicable abort mode regions. Also, the time to perilune of the mode II intermediate ellipses varies only within 1.5 hours throughout the launch window. Finally, the perilune altitude of the mode II intermediate ellipse drops below 40 n. mi. for launches late in the launch window if an SPS failure occurs early in the mode II region. In this early mode II region, however, a mode I abort would have been attempted.

4.6 Abort Capability for a September 13, 1969, Hybrid Lunar Mission (78° azimuth, first opportunity)

In this section, the LOI abort requirements are summarized for another typical launch date in the Apollo 11 (Mission G) launch window. Note, however, that these data also apply to a nominal launch date of the G-2 mission which would be flown if a lunar landing does not occur on Apollo 11 (Mission G).

The instantaneous conic parameters during the LOI burn for a September 13, 1969, launch are shown in figure 12. The 15-hour period which defines the start of the mode III region occurs at 2^m54^s into the LOI burn. The LOI ΔV magnitude is shown in figure 13 as a function of SPS burn time. The FCUA abort ΔV necessary for aborts throughout the LOI burn is shown in figure 14. For this LOI burn, the region in which DPS capability does not exist is very small (8 sec), because the hybrid translunar trajectory is much nearer a free-return trajectory than the trajectory for the July 21, 1969, hybrid mission (section 4.4). The largest APS ΔV required is 70 fps or a burn of approximately 44 seconds duration, but for a ΔV of this magnitude, RCS capability would probably exist.

A return to the MPL would be preferred, however, and the ΔV requirements are shown in figure 15. By comparison of the FCUA and MPL data, the ΔV penalty can be assessed. The maximum APS ΔV required for an MPL return would be 330 fps or a burn of approximately 3^m16^s duration.

The GETL for the FCUA mode I and mode II aborts of figure 14 are shown in figure 16. The GETL that corresponds to MPL and AOL returns are indicated in figure 15. Although the MPL return would be preferred, the figure can be used to estimate an alternate landing area closer to the FCUA return point if abort ΔV is to be minimized.

The characteristics of the mode II abort required for a September 13, 1969, mission are shown in figures 17(a) through 17(d). The corrective burn ΔV magnitude is shown in figure 17(a) as a function of LOI burn time. Note that FCUA mode II aborts prior to 1^m58^s would require an APS burn after a second DPS burn which used the remaining DPS propellant. Although the mode II first burn is nominally at LOI ignition plus 2 hours, the maximum allowable time to delay abort ignition is shown in figure 17(b). For delays later than this maximum time, a perilune altitude of less than 40 n. mi. or a time to perilune of greater than 40 hours would result in the intermediate ellipse if the nominal ΔV_1 were applied. However, if a higher ΔV_1 were used, an acceptable perilune and period could result; although the total mode II ΔV would be increased. The time from the

corrective maneuver to perilune and the perilune altitude of the intermediate ellipse are shown in figures 17(c) and 17(d). Data are shown for a corrective maneuver initiated at 2 hours and at 5 hours past LOI ignition. It can be seen that the time to perilune is slightly affected as the abort is delayed, but the primary effect is a reduction in perilune altitude.

The mode I abort and mode II corrective maneuver ignition times are determined by LM activation times because an early burn is desirable. However, the mode II second DPS burn and mode III abort ignition time are determined by the period of the lunar orbit achieved and are shown in figure 18.

To summarize the LOI abort capability for a September 13, 1969, hybrid lunar mission, the LM propulsion systems have the performance capability to return the spacecraft to earth for an SPS failure at any time during the LOI burn. However, the DPS cannot provide the necessary ΔV in a region from 1^m50^s to 1^m58^s in the burn. It has been shown that the APS has the additional performance capability required to abort in this critical region of the burn.

4.7 Typical Hybrid Mission LOI Crew Chart (July 21, 1969, 72° azimuth, first opportunity)

A crew chart to be used during LOI to provide an immediate abort capability (LOI ignition plus 15 min) if SPS problems are indicated was discussed in section 8.2.9 of reference 1. Because the nominal July 16, 1969, free-return lunar mission was considered in reference 1, only the differences encountered in the use of the chart for a hybrid mission are presented here.

The crew chart is shown in figure 19. The region of the burn in which a DPS backup is not available (section 4.4) is indicated on the figure. Two major differences in the use of this chart for a hybrid mission are as follows.

1. The ΔV required at the start of the LOI burn (DVM = 0 fps) is 650 fps compared to 0 fps for a free-return.
2. Manual shutdown and use of the 15-minute chart is not recommended for the region in which a DPS backup is not available. As an illustration, if an SPS problem were apparent at a DVM = 500 fps, continuation of the burn to the DPS mode II region (DVM = 860 fps) would require 360 fps of SPS ΔV compared to a 15-minute abort ΔV of 1300 fps. In other words,

manual shutdown is not recommended for a region in which no DPS backup is available because a much smaller ΔV is required to assure a DPS backup than is required to initiate a 15-minute abort.

The procedures for use of the 15-minute chart are contained in reference 1 and are not repeated here. Note that the gimbal angles are not contained on the preliminary crew chart in figure 19 because a lunar landing site REFSMMAT was not available at the date of publication. The landing points associated with specific LOI shutdowns are included in table I.

4.8 Summary of LOI Abort Requirements as a Function of Hybrid Trajectory Characteristics

The FCUA abort requirements for the entire LOI burn were shown for three specific cases: a July 16, 1969, launch (free return), a July 21, 1969, launch (hybrid mission); and a September 13, 1969, launch (hybrid mission). The purpose of this section is to summarize LOI abort requirements and to attempt to relate them to the geometry of the trans-lunar trajectory.

The FCUA abort ΔV for the three specific LOI burns are summarized in figure 20. The mode I aborts and mode II corrective maneuvers are initiated at LOI_{IG} plus 2 hours. The bar chart indicates where each abort mode applies. As indicated in previous sections, the gap region between mode I and mode II increases as the FCUA abort ΔV for the no-LOI-burn case increases. A summary of the abort ΔV requirements for an SPS failure at LOI ignition is presented in table II for various hybrid launch dates (ref. 3). The time of ignition is assumed to be 2 hours past nominal LOI ignition and is determined by the IM activation times. Included in the table is the perilune altitude of the initial free-return trajectory prior to the hybrid midcourse maneuver.

From table II, it can be seen that as the free-return perilune altitude (prior to the hybrid midcourse) increases the abort ΔV required (from the hybrid trajectory) also increases. However, another important variable that affects the abort ΔV is the latitude of the free-return perilune. Its effect is shown in the case of the September 13, 1969, hybrid mission for which the relatively low 100-n. mi. free-return perilune altitude still is accompanied by a large abort ΔV . This large ΔV is the result of the perilune latitude of the free-return trajectory. Although this latitude is optimum for the hybrid trajectory from an SPS standpoint, it causes a large abort ΔV . The relationships of the various trajectory parameters such as perilune altitude and latitude can be explained only when more LOI burns are evaluated.

5.0 CONCLUSIONS

The primary differences between the LOI abort requirements for free-return and hybrid missions are presented. Depending on the launch date, a region may occur in the LOI burn in which a DPS return-to-earth maneuver is not possible because of high ΔV requirements. In this region, however, the APS has the necessary ΔV capability to complete the DPS abort.

TABLE I.- LOI 15-MINUTE CREW CHART RESULTS

[July 21, 1969, hybrid mission]

LOI burn time, min:sec	LOI ΔV DVM, fps	Abort ΔV , fps	Landing conditions	
			Latitude, deg:min N	Longitude, deg:min E
0:00	0	655	17:35	52:18
0:40	282	1011	18:17	53:07
1:20	572	1401	19:05	54:59
2:00	871	1823	19:58	57:40
2:40	1178	2275	20:58	61:11
3:20	1496	2759	22:05	65:30

TABLE II.- SUMMARY OF DPS ΔV AND PERILUNE ALTITUDE OF THE
FREE-RETURN PHASE FOR SPECIFIC HYBRID MISSIONS

Date, month:day	Free-return h_p , n. mi.	No-LOI burn (LOI_{IG}) plus 2 hr) abort ΔV , fps	Time of abort, t_D , hr
7-21	800	942.5	2
8-14	550	609.5	2
8-16	975	1011.5	2
8-20	400	828.5	2
9-13	100	431.5	2
9-15	350	1176.5	2
9-18	1400	1579	2

LOI MODE I ABORT

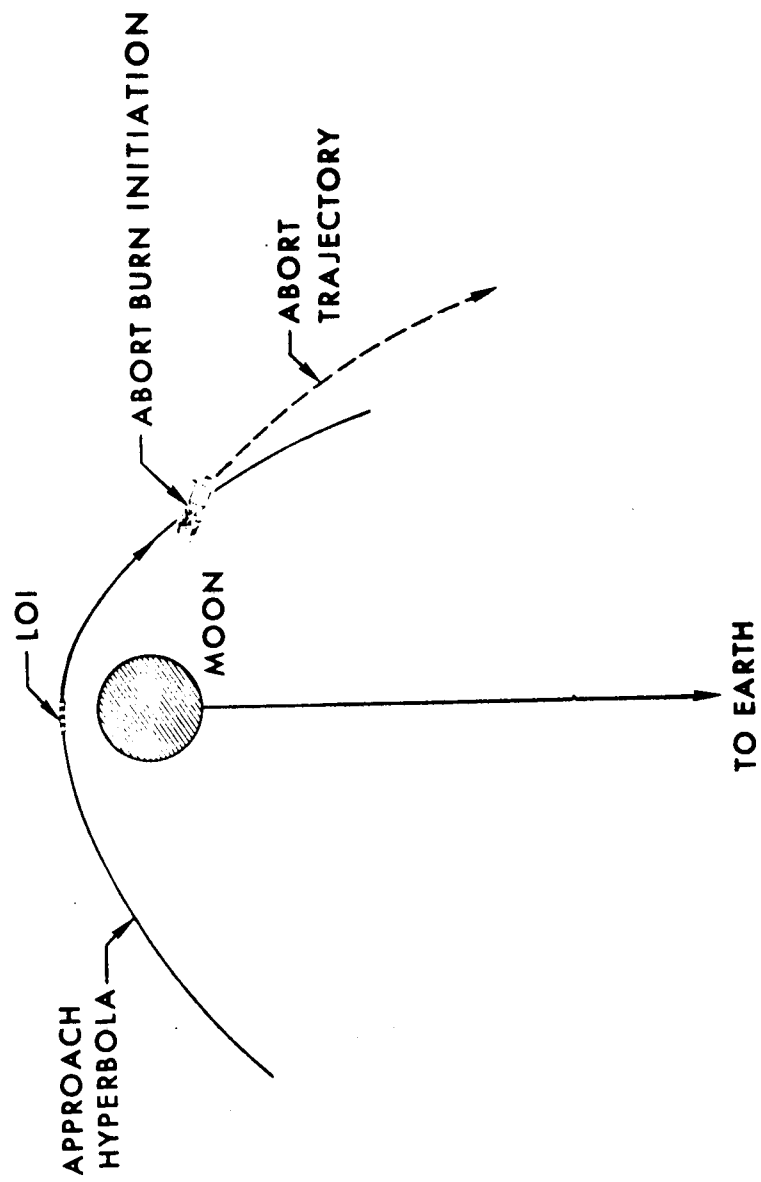


Figure 1.- Mode I abort geometry following an SPS failure during LOI.

LOI MODE II ABORT

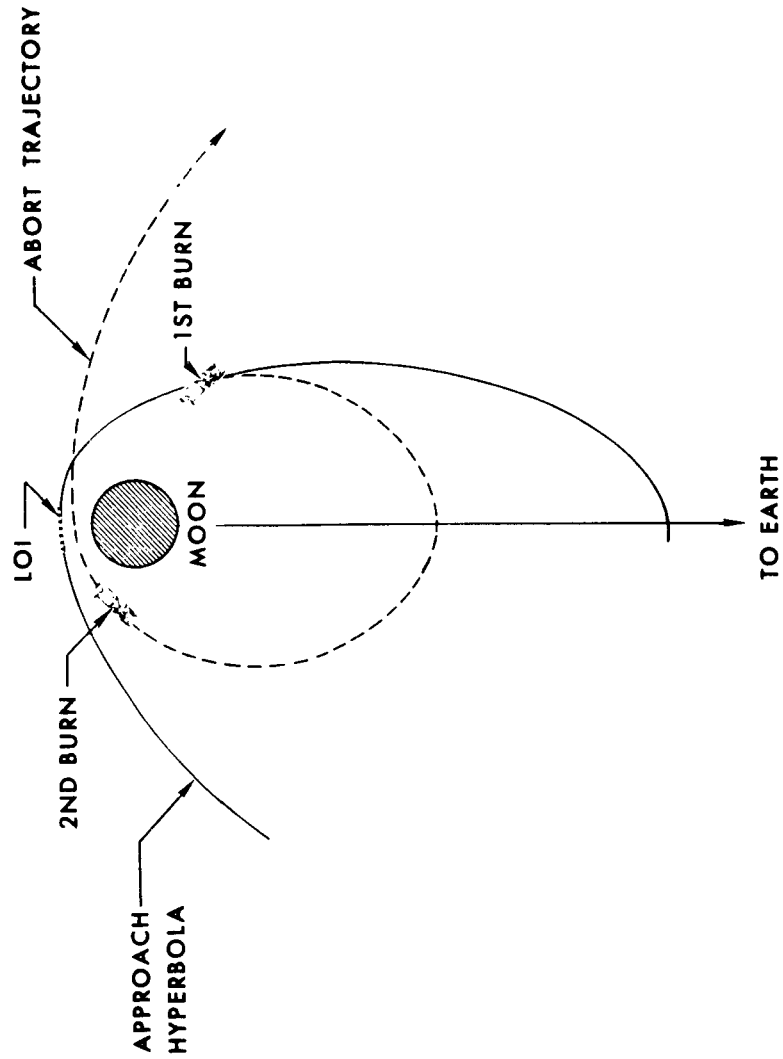


Figure 2.- Mode II abort geometry following an SPS failure during LOI.

LOI MODE III ABORT

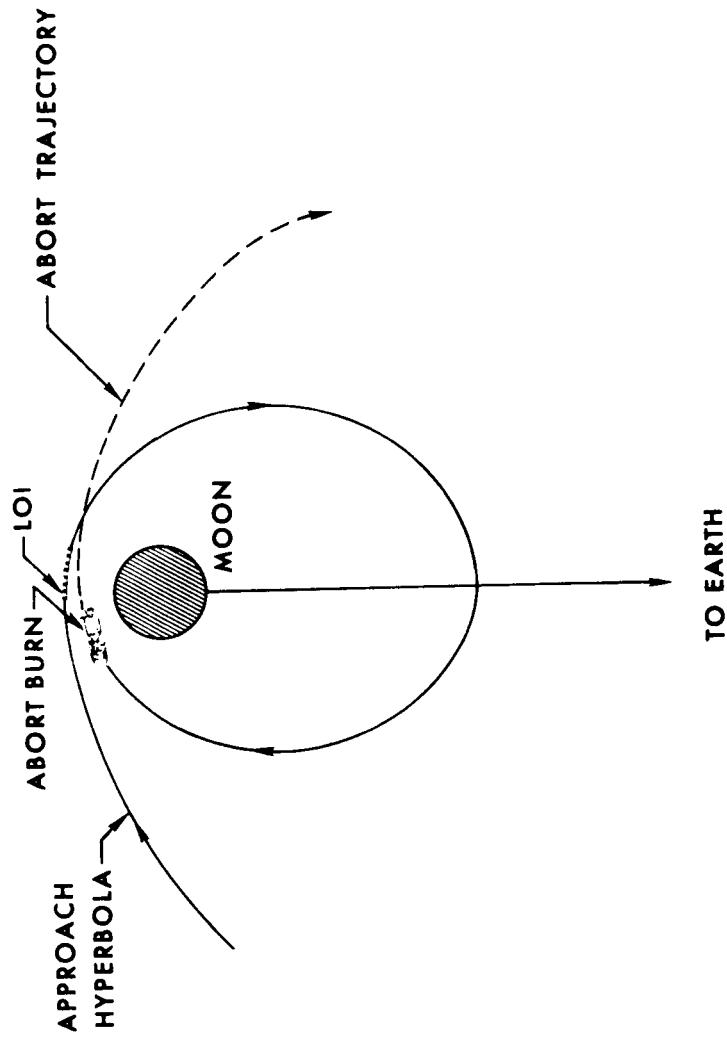
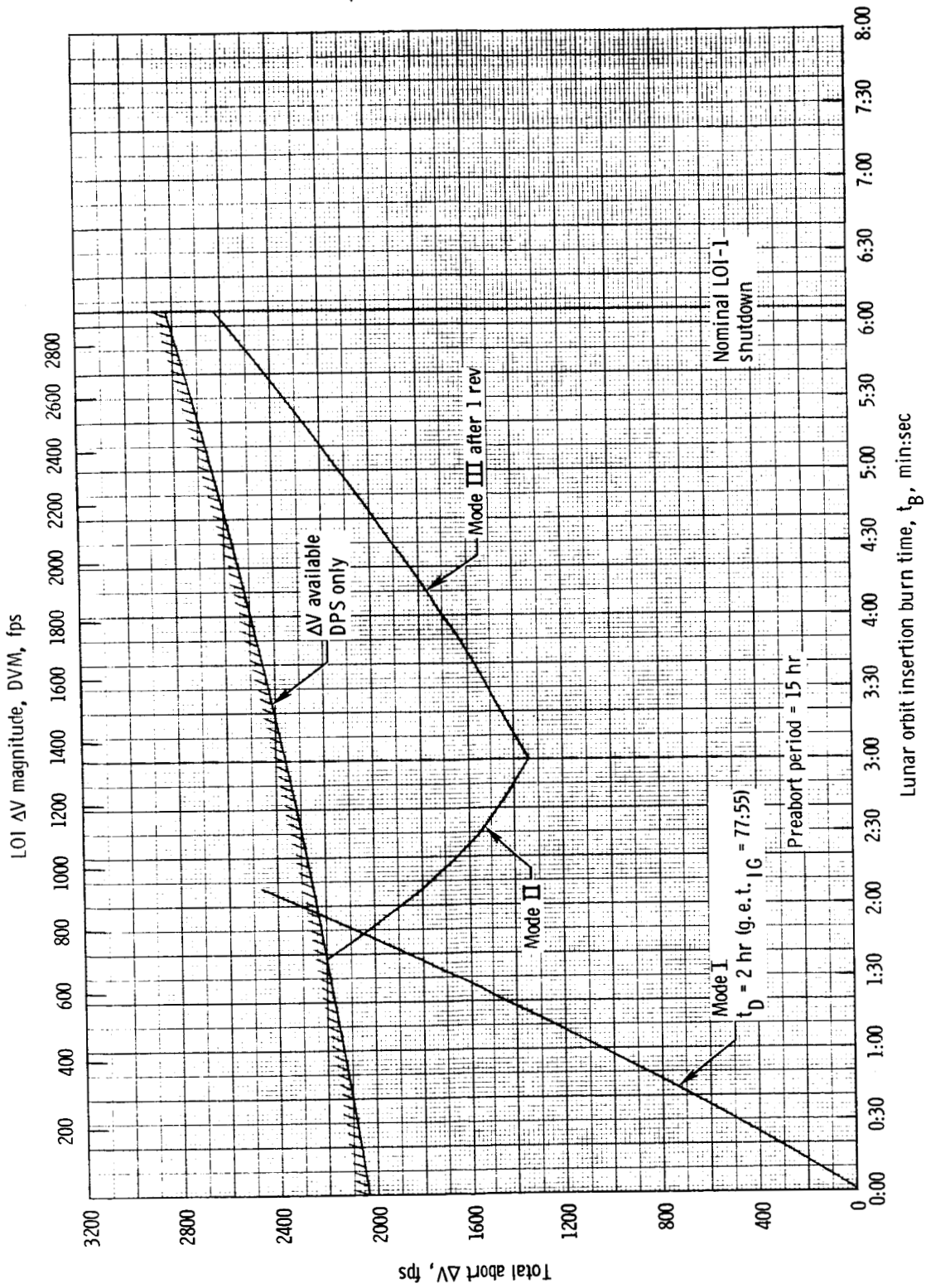
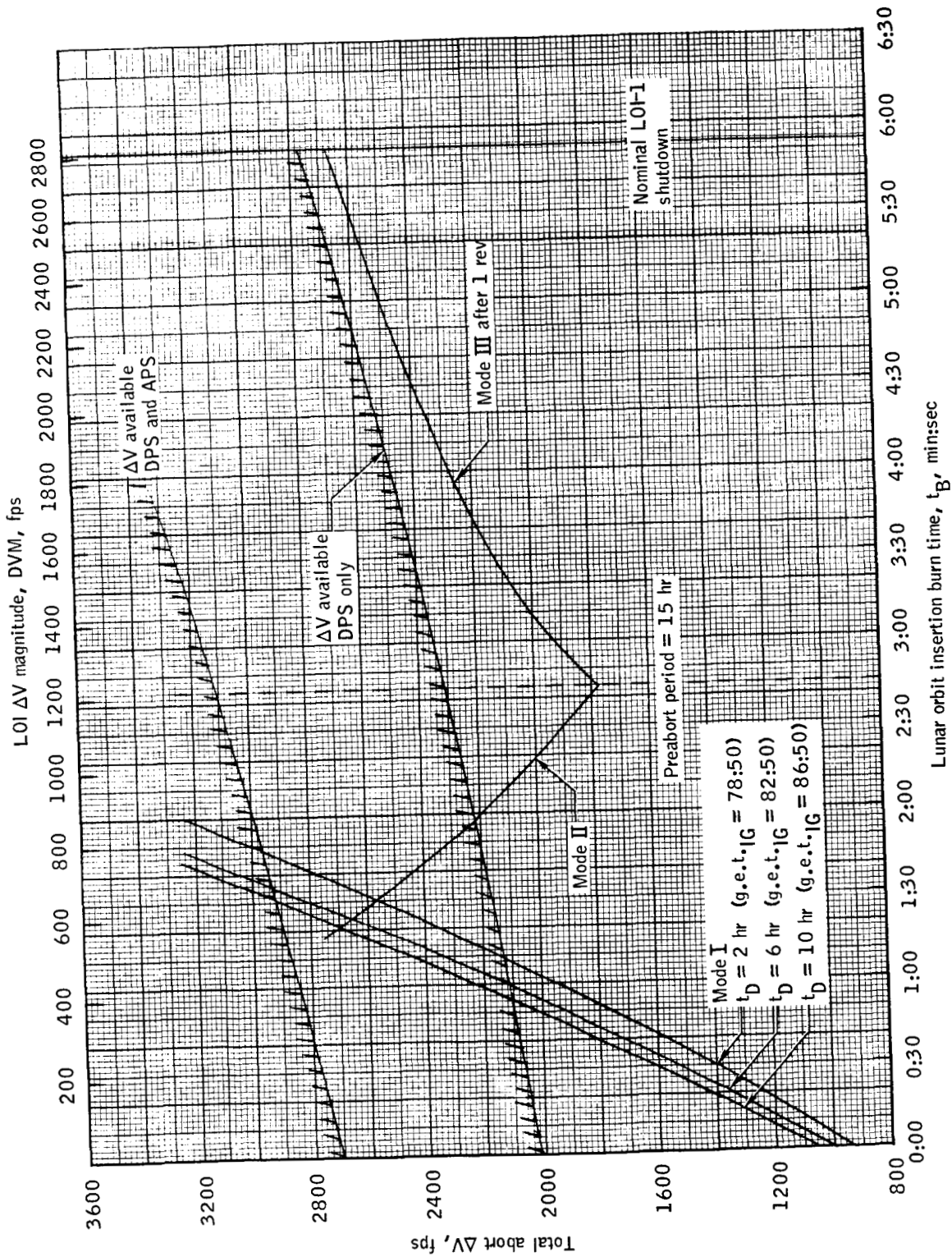


Figure 3.- Mode III abort geometry following an SPS failure during LOI.



(a) July 16, 1969 (free return), 72° azimuth, first opportunity.

Figure 4. - Summary of FCUA LOI abort ΔV requirements as a function of burn time.



(b) July 21, 1969 (hybrid), 72° azimuth, first opportunity.

Figure 4.- Concluded.

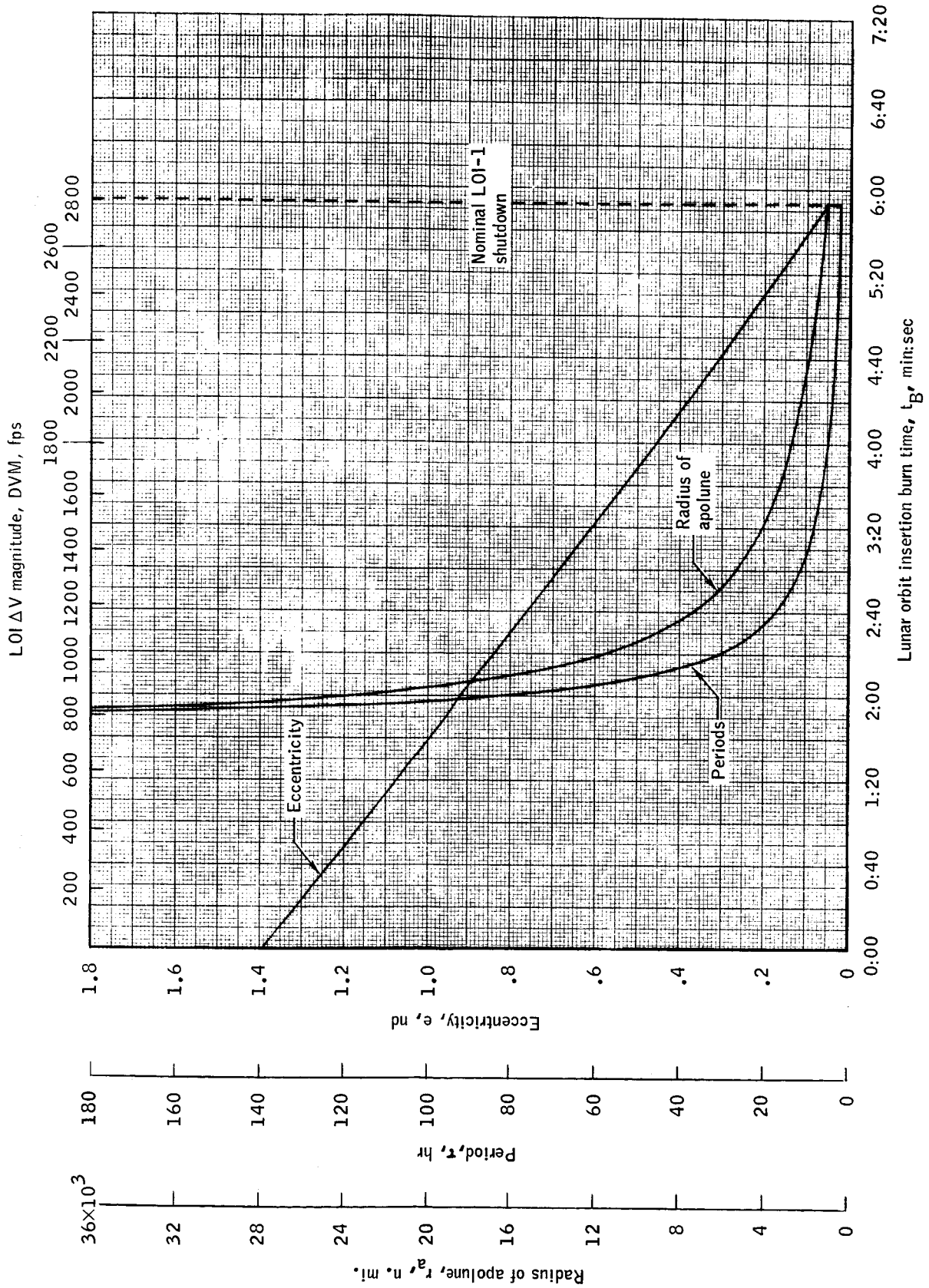


Figure 5.- Conic parameters as a function of LOI burn time, July 21, 1969 (72° azimuth, first opportunity).

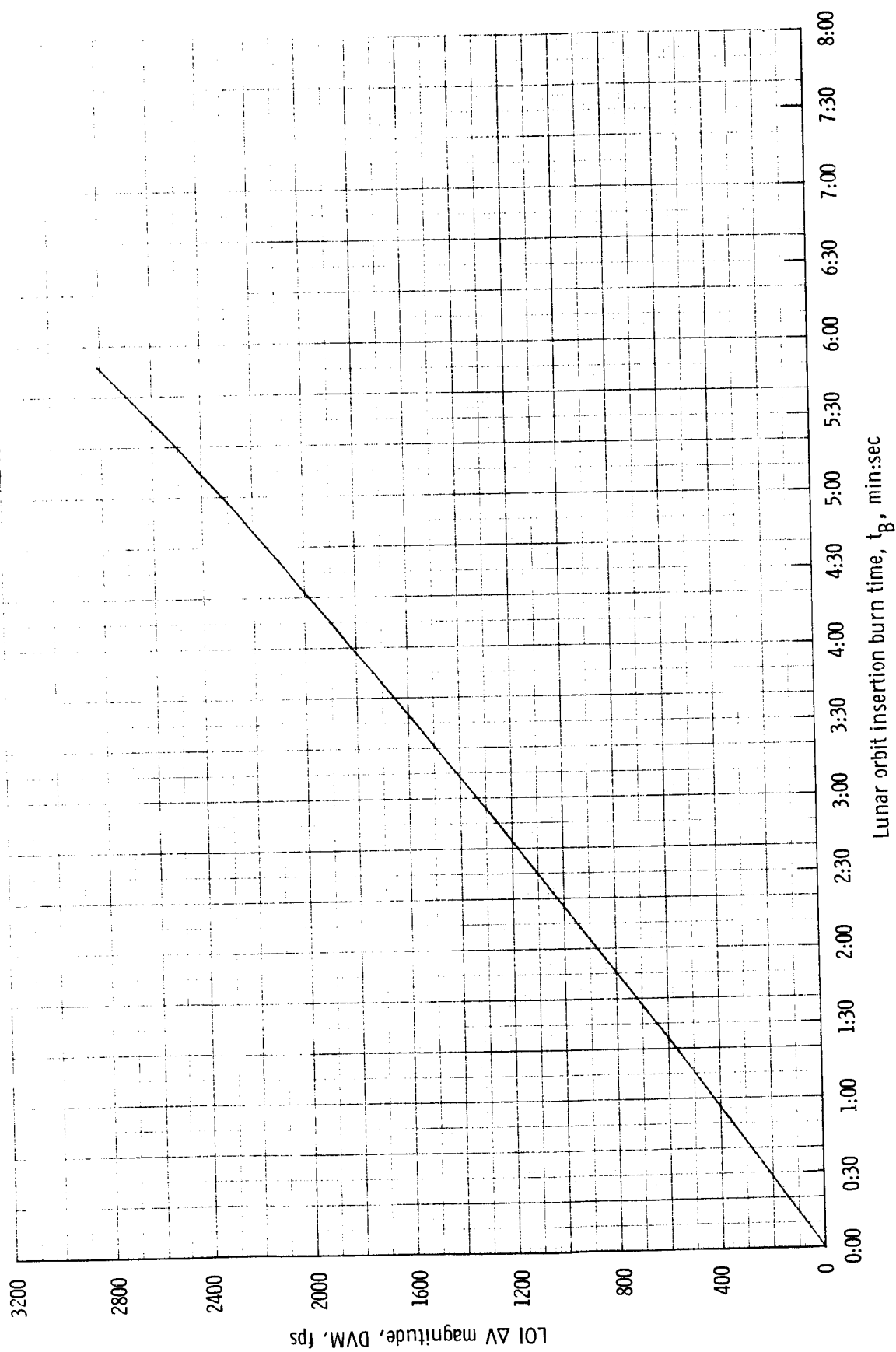


Figure 6. - LOI ΔV magnitude as a function of SPS burn time, July 21, 1969 (72° azimuth, first opportunity).

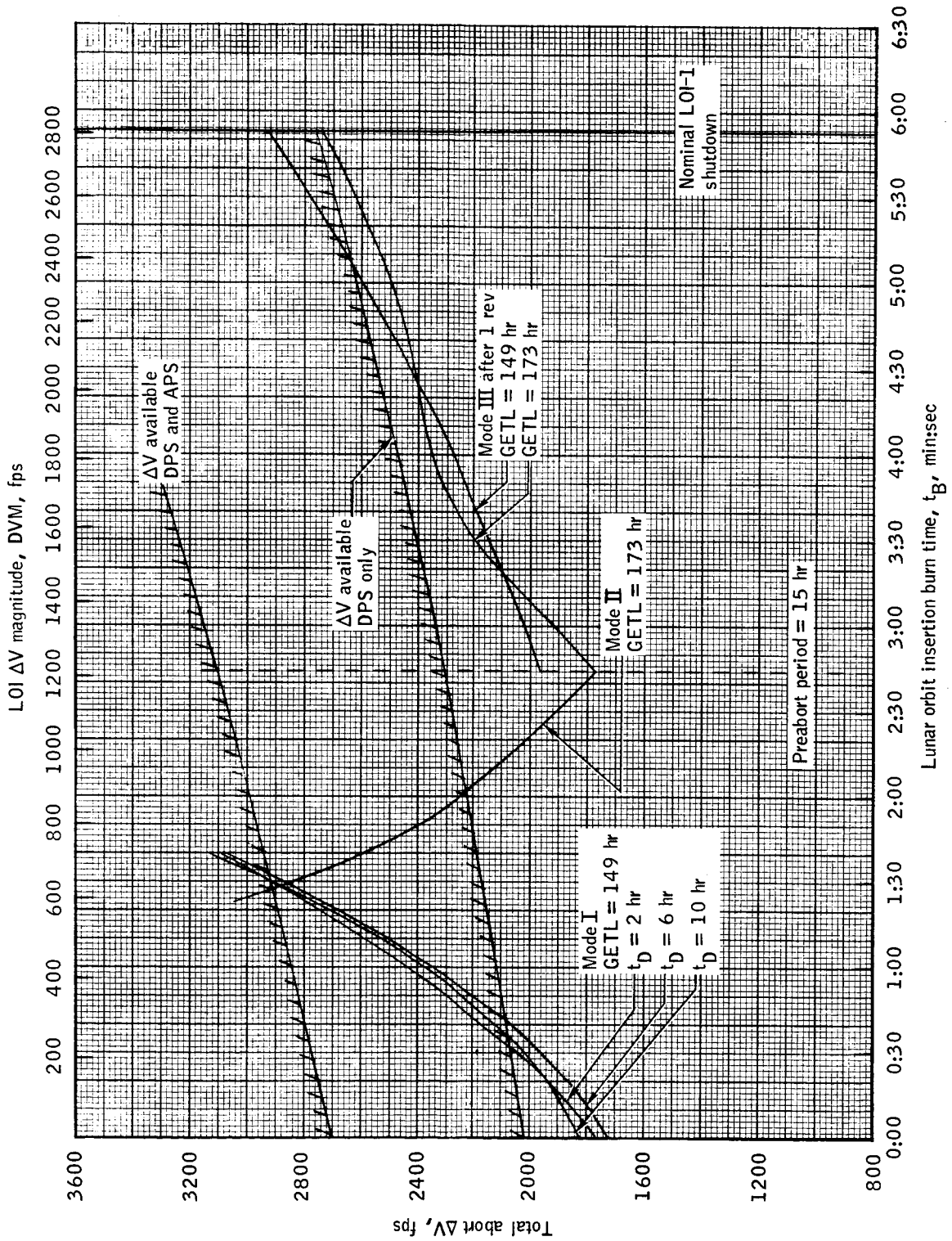


Figure 7. - Summary of MPL LOI abort ΔV requirements for July 21, 1969, hybrid mission (72° azimuth, first opportunity).

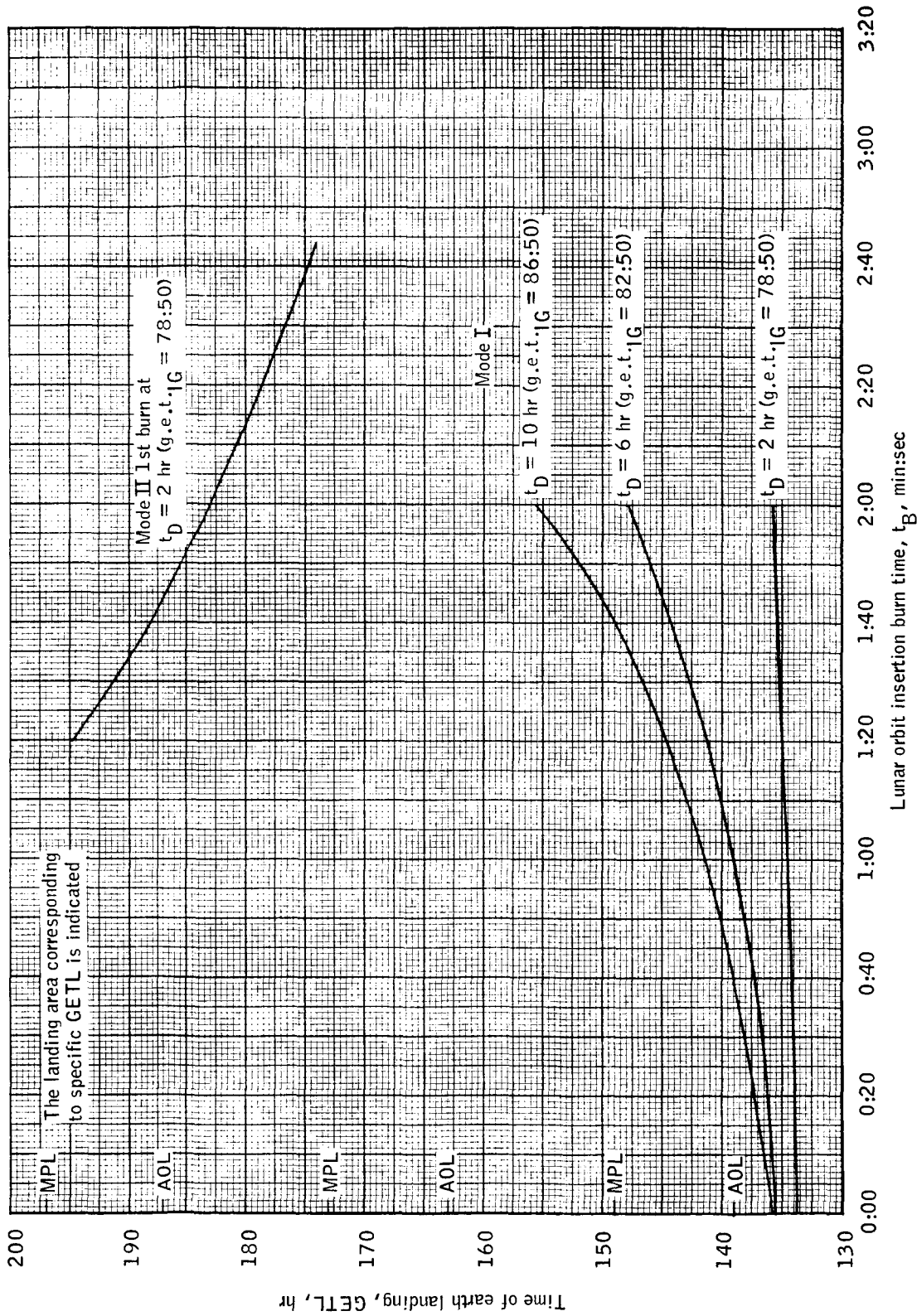
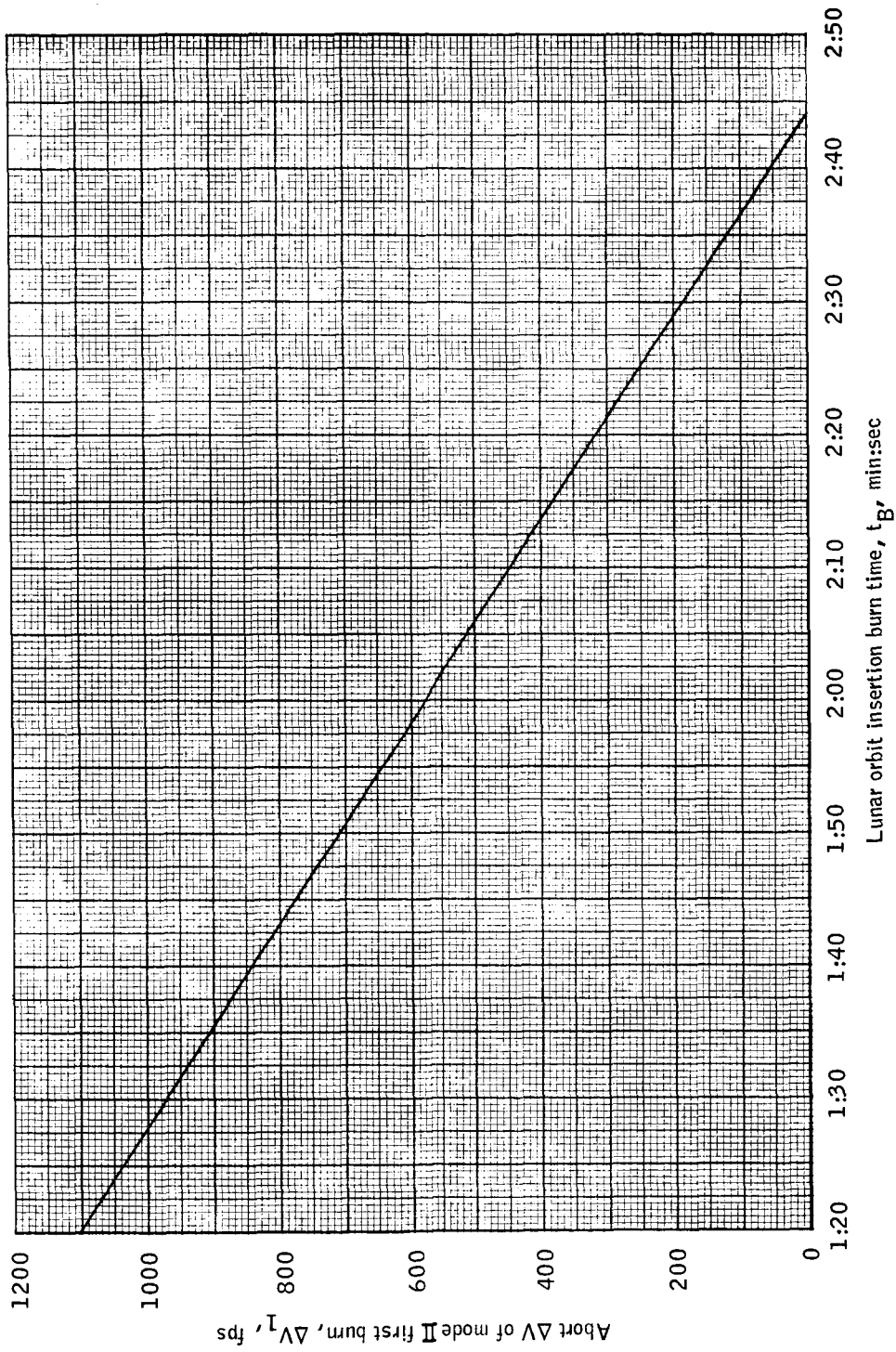
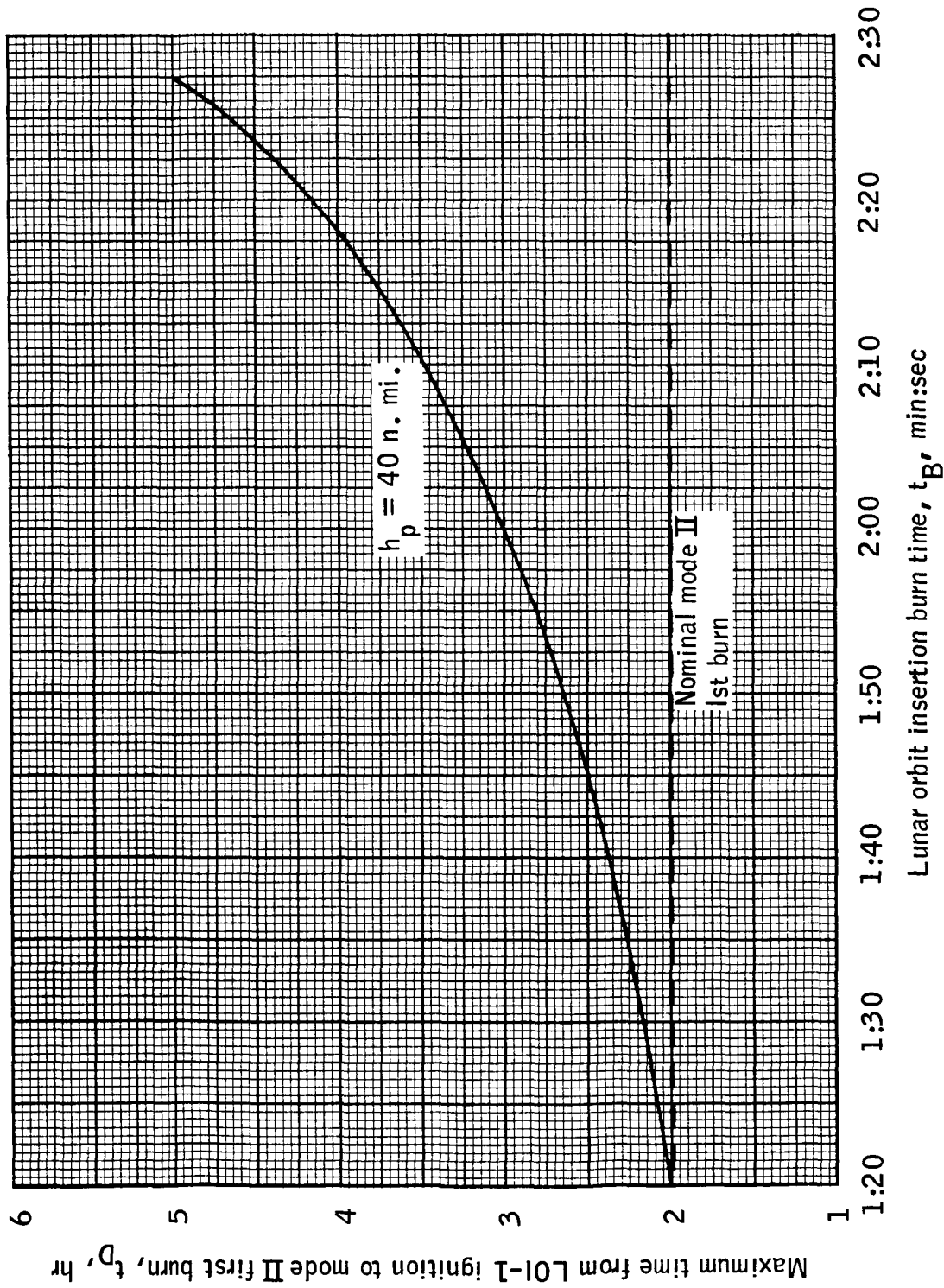


Figure 8.- Ground elapsed time of landing for FCUA mode I and II aborts (July 21, 1969).



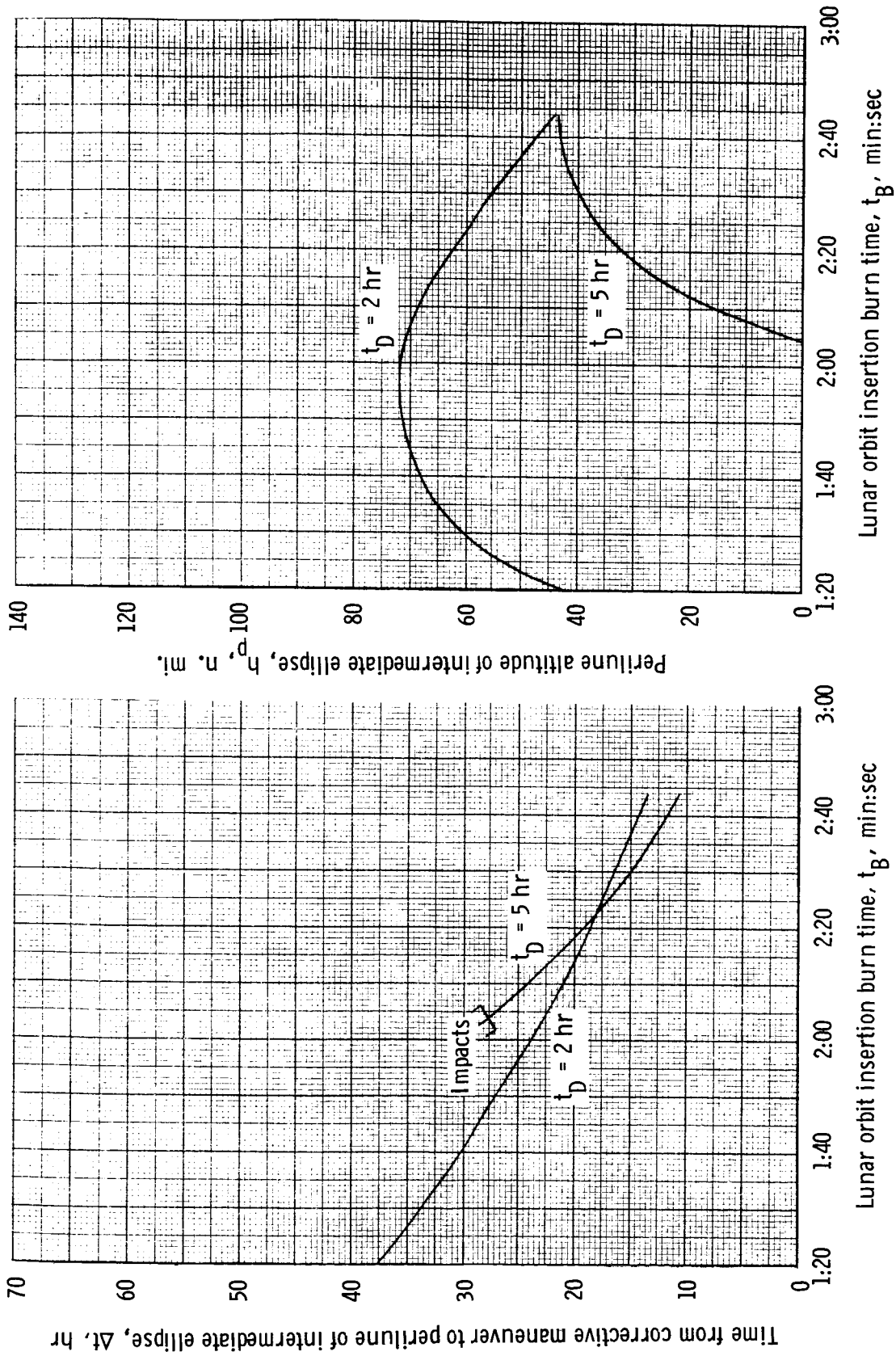
(a) First burn ΔV magnitude (corrective maneuver).

Figure 9.- Mode II abort analysis as a function of LOI burn time (July 21, 1969).



(b) Maximum allowable delay time to corrective maneuver ignition.

Figure 9.- Continued.



(c) Time from corrective maneuver to perilune of intermediate ellipse.

(d) Perilune altitude of intermediate ellipse.

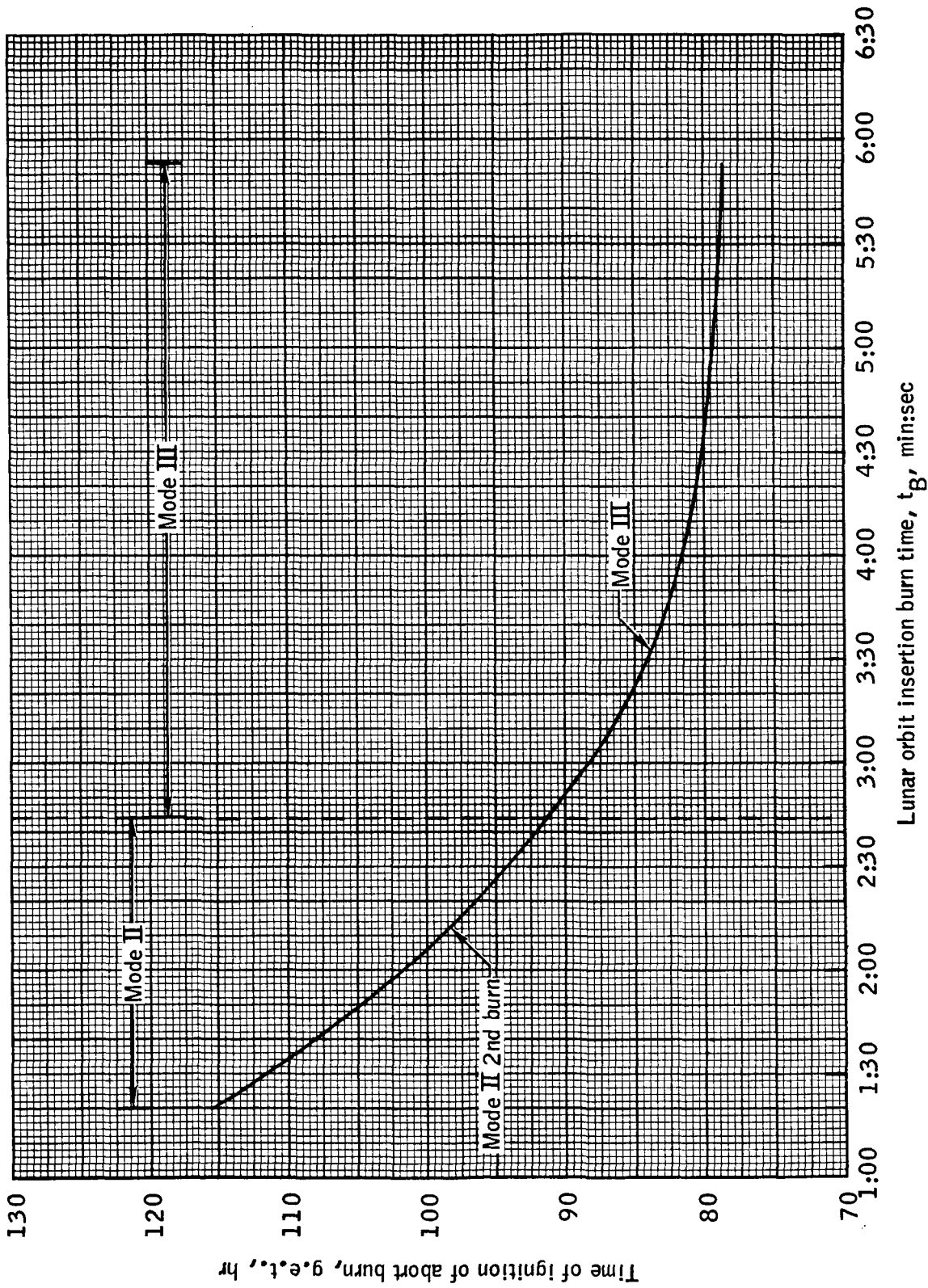


Figure 10.- Ground elapsed time of ignition of FCUA mode II second burn and mode III abort as a function of LOI burn time (July 21, 1969).

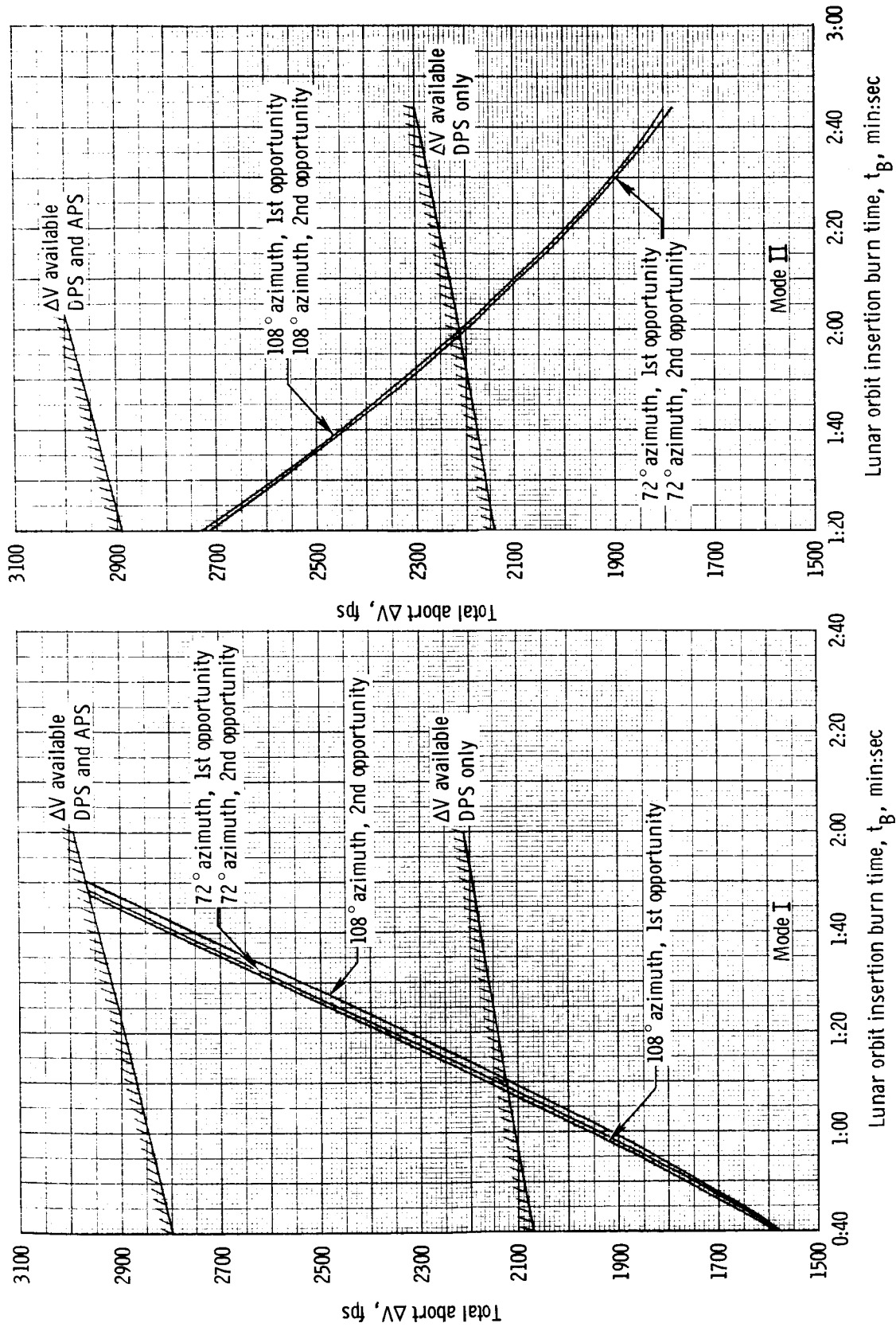
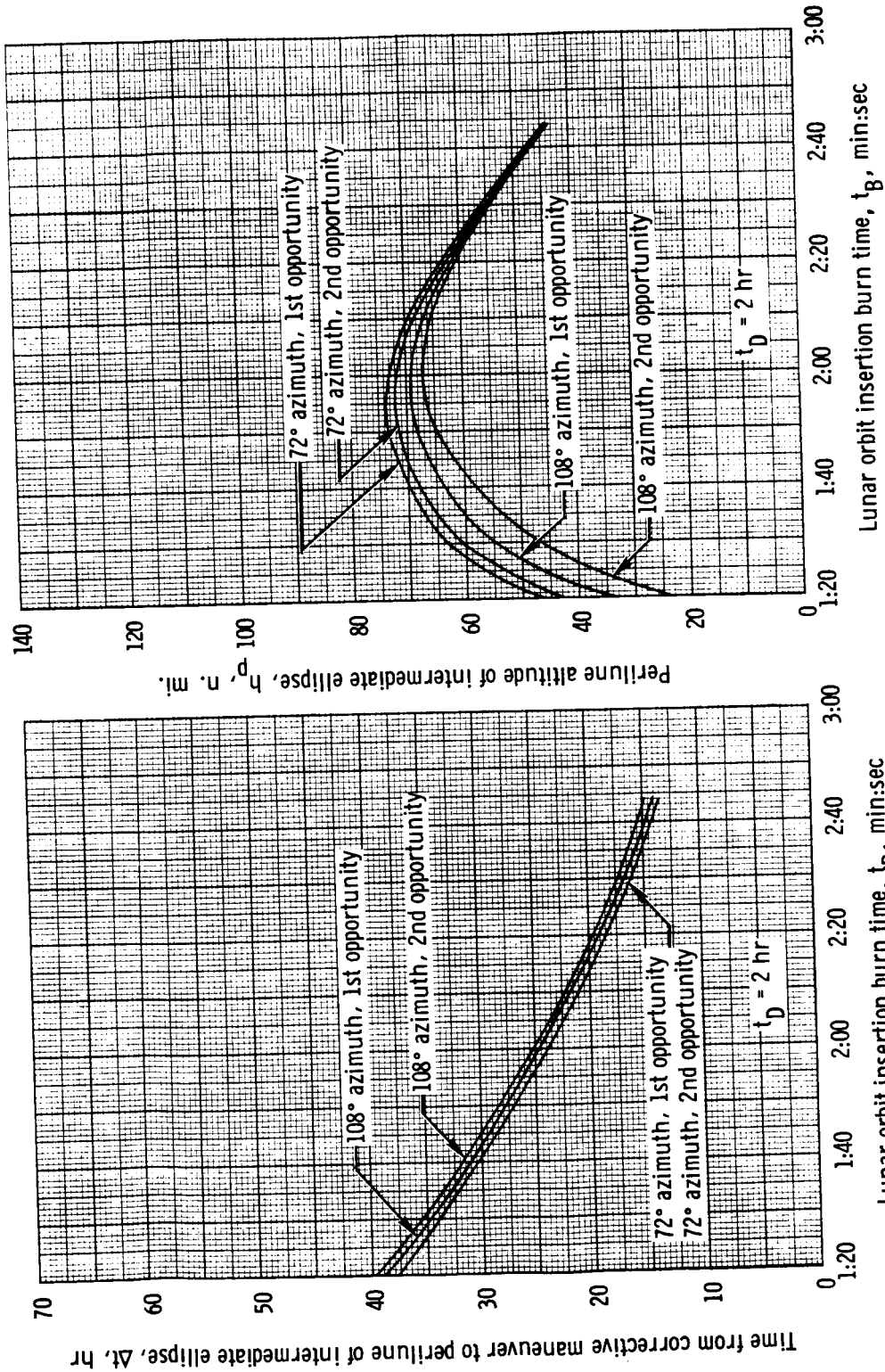
(a) Mode I ΔV as a function of LOI burn time.(b) Mode II total ΔV as a function of LOI burn time.

Figure 11. - FCUA abort analysis for July 21, 1969 launch window.



(d) Perilune altitude of intermediate ellipse.

(c) Time from mode II corrective maneuver to perilune of intermediate ellipse.

Figure 11. - Concluded.

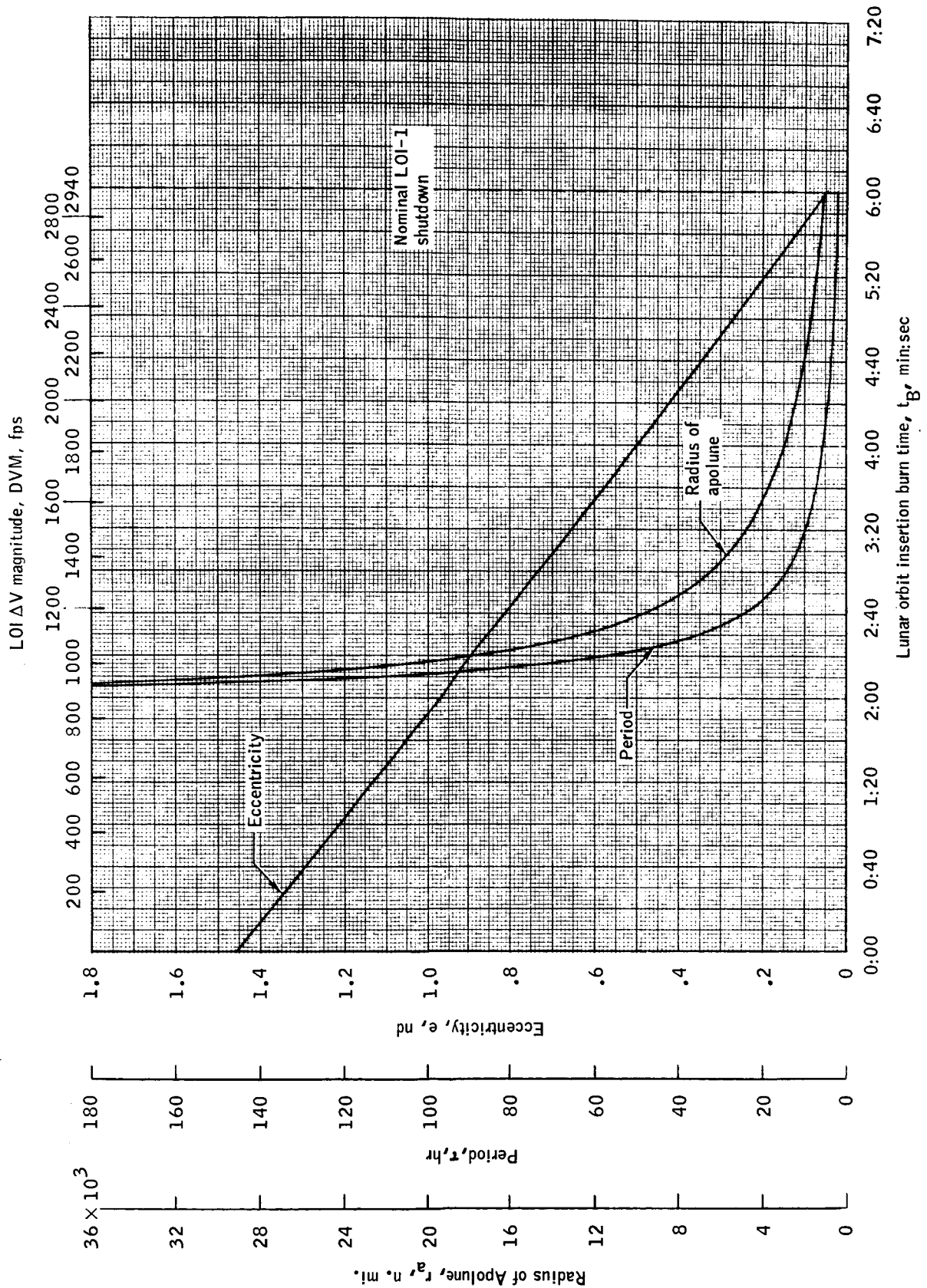


Figure 12.- Conic parameters as a function of LOI burn time, September 13, 1969 (78° azimuth, first opportunity).

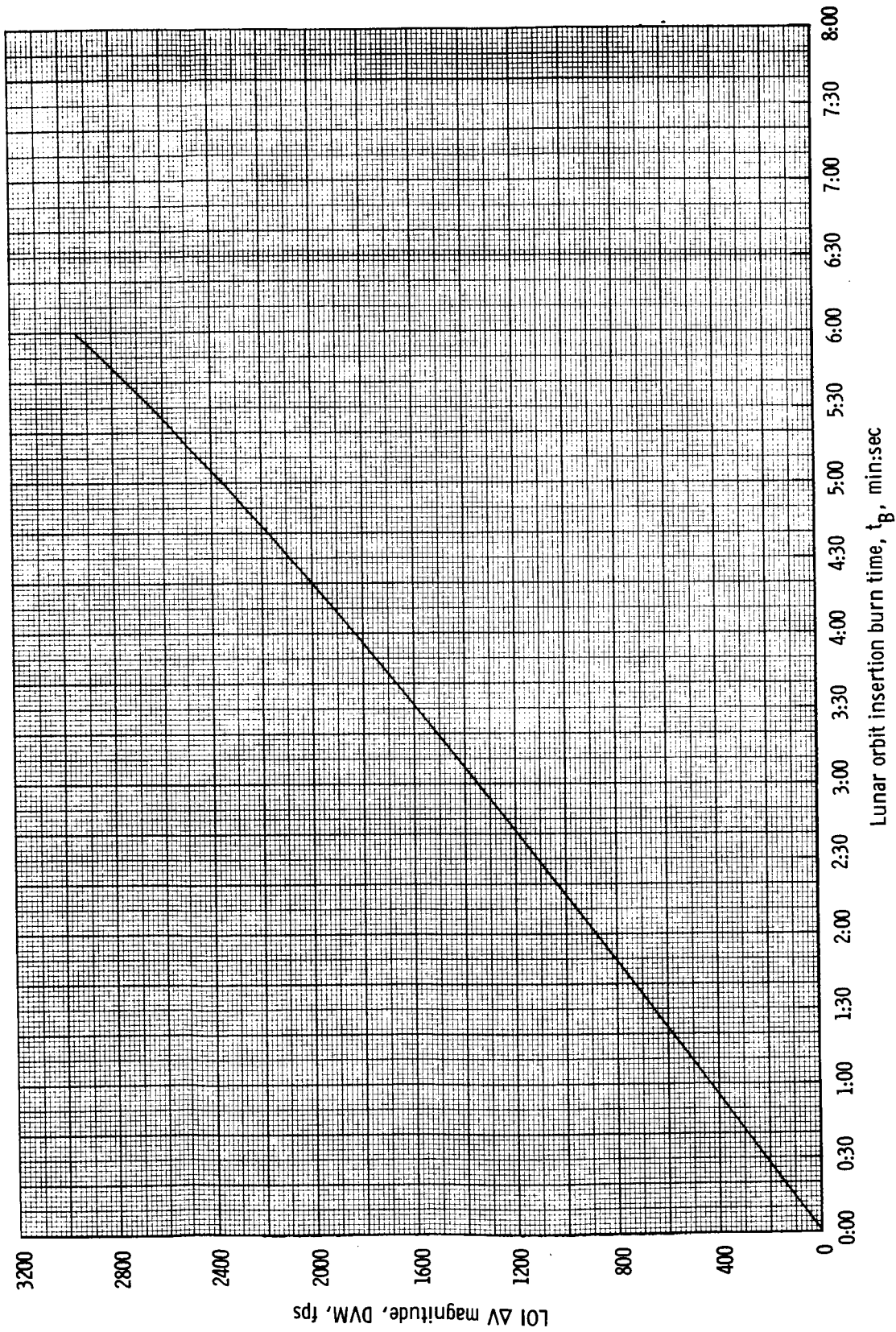


Figure 13. - LOI ΔV magnitude as a function of SPS burn time, September 13, 1969 (78° azimuth, first opportunity).

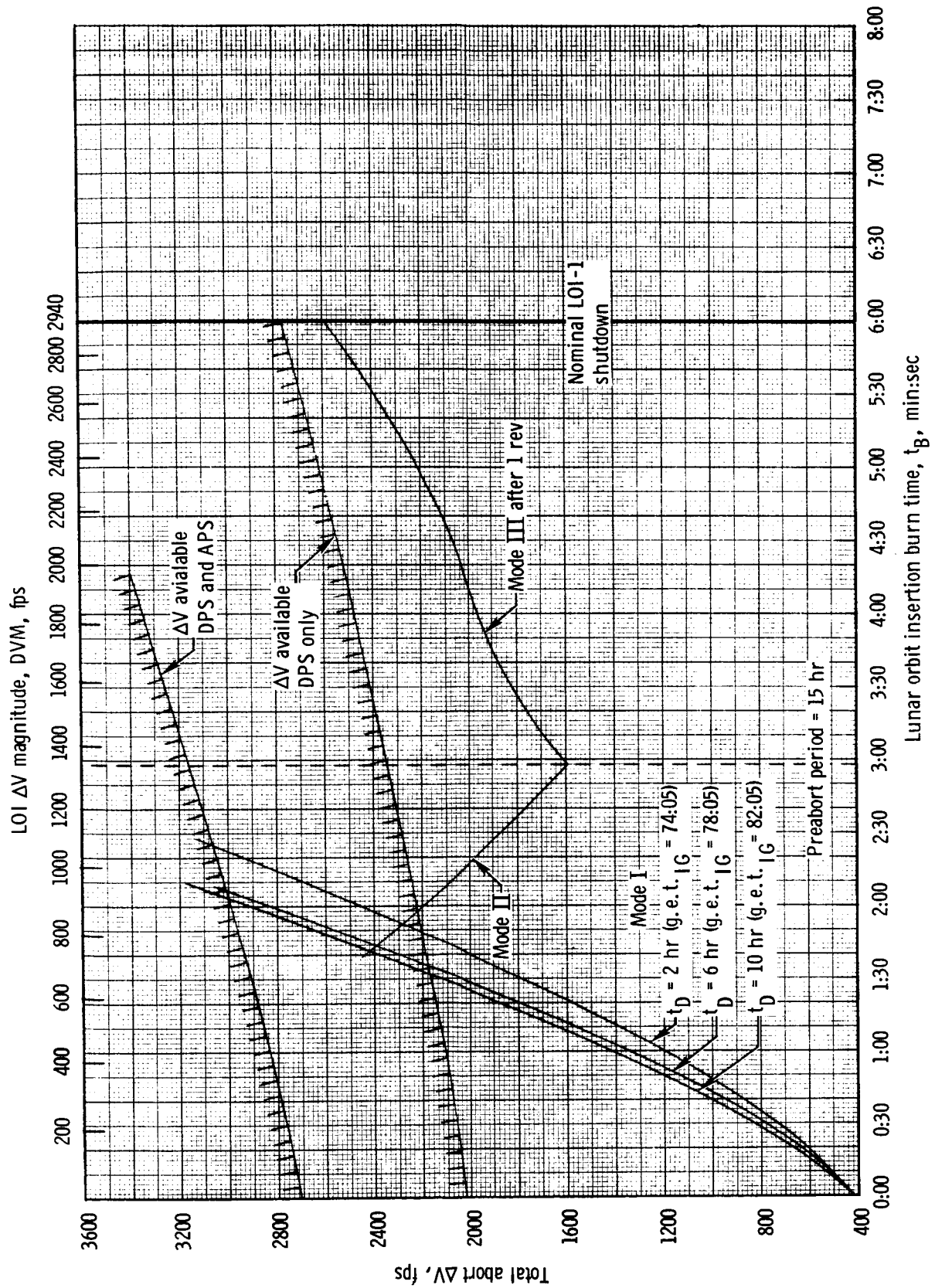


Figure 14. - Summary of FCUA LOI abort ΔV requirements for a September 13, 1969, hybrid mission (78° azimuth, first opportunity).

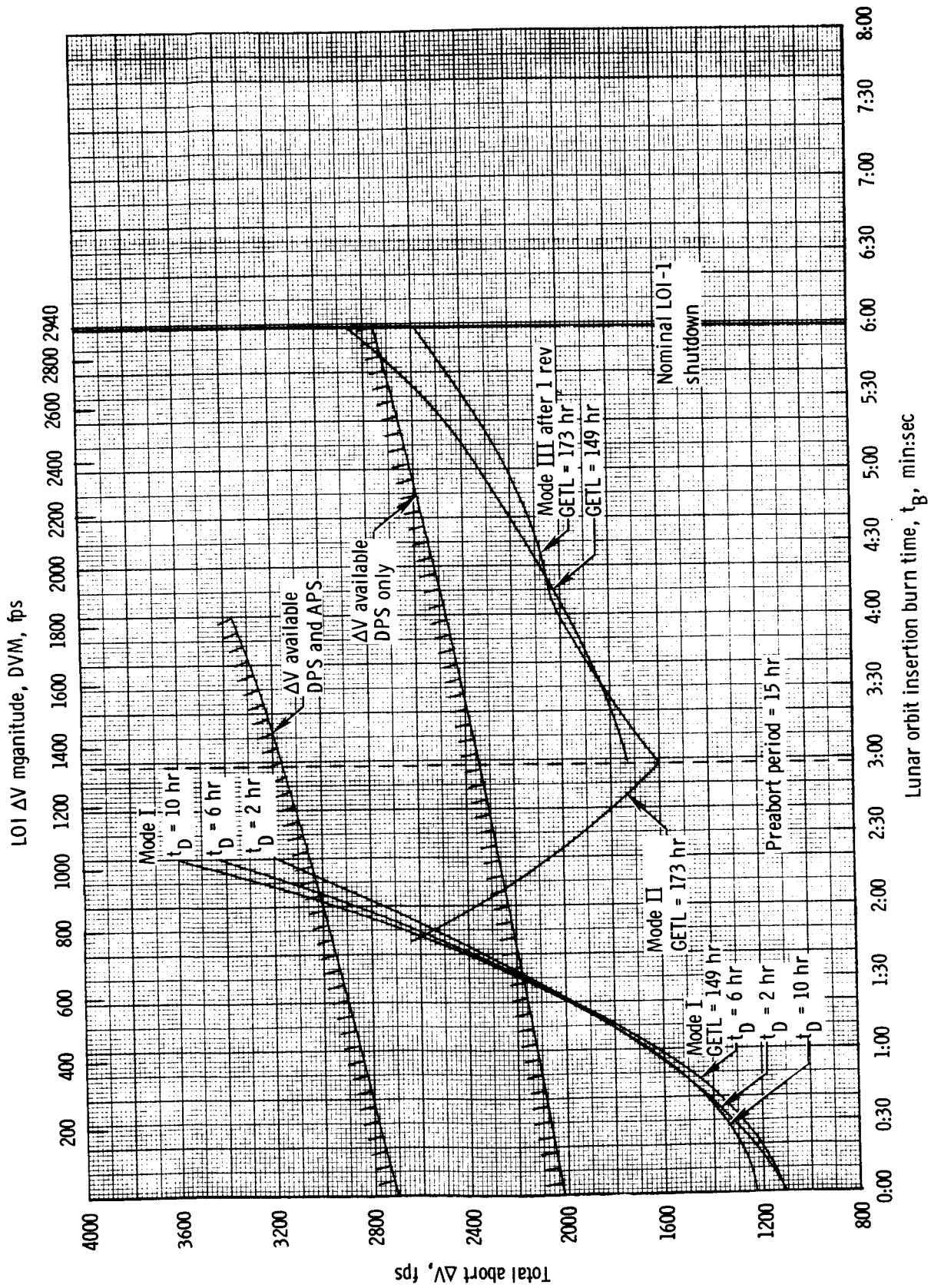


Figure 15. - Summary of MPL LOI abort ΔV requirement for September 13, 1969, hybrid mission (78° azimuth, first opportunity).

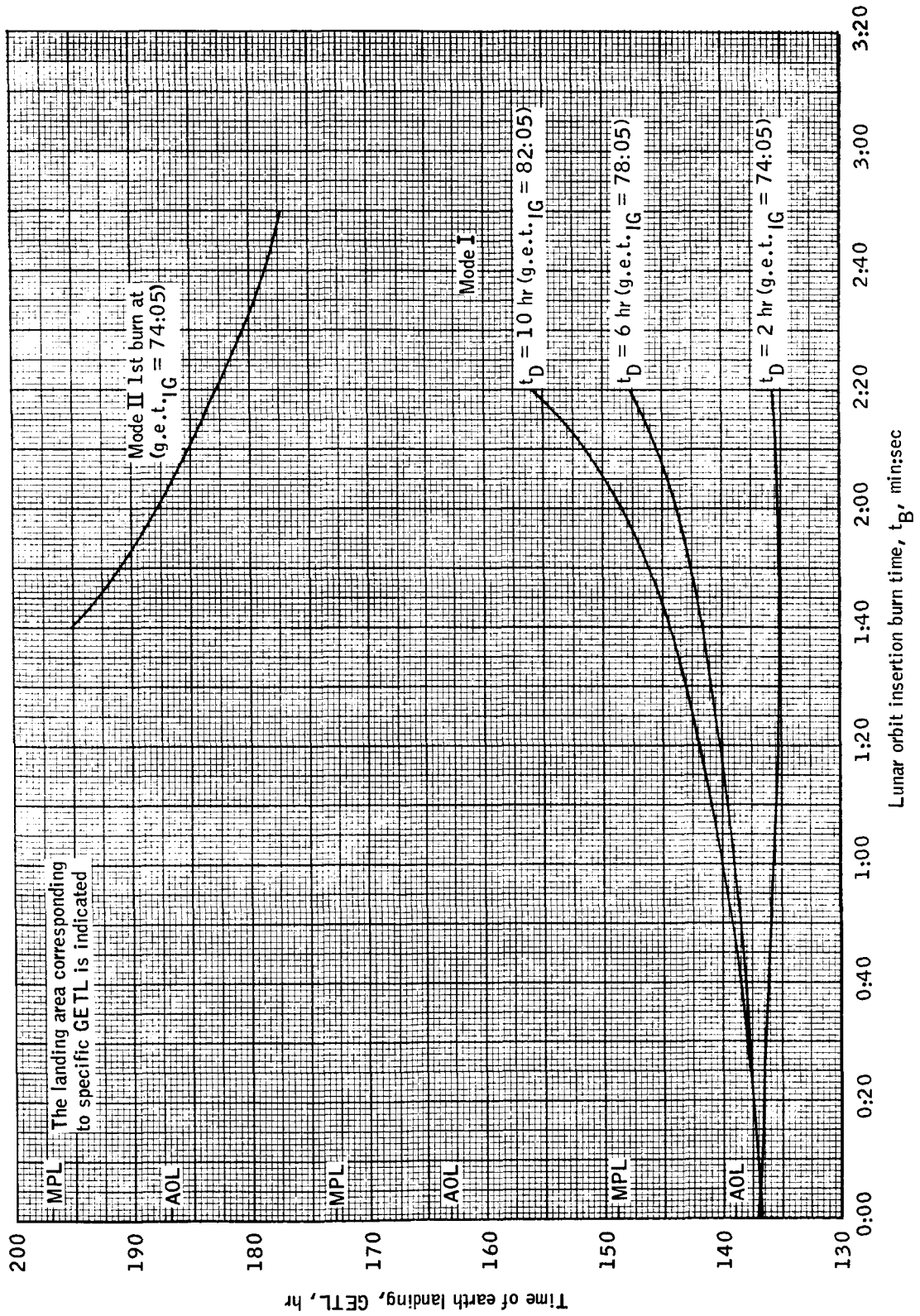
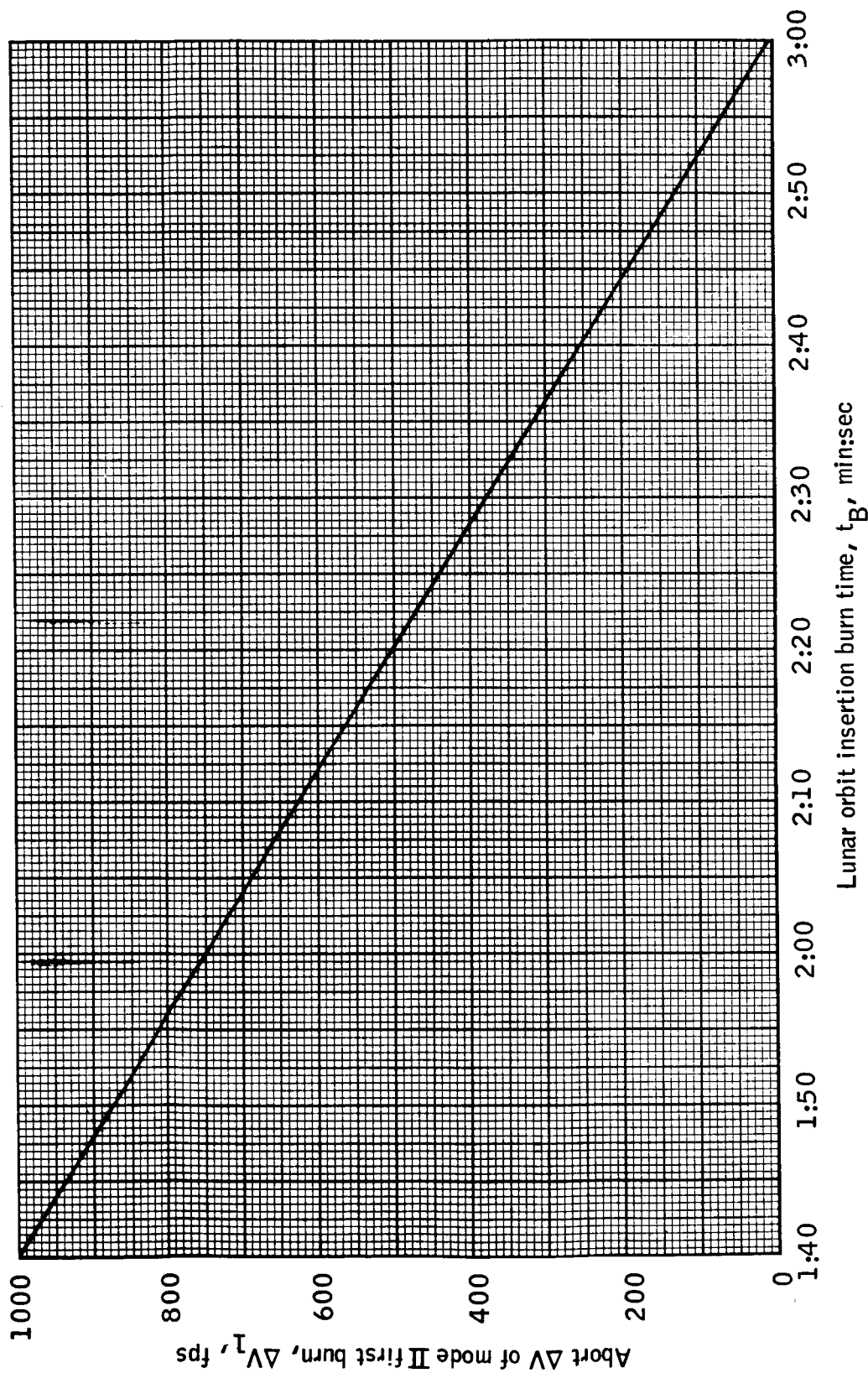
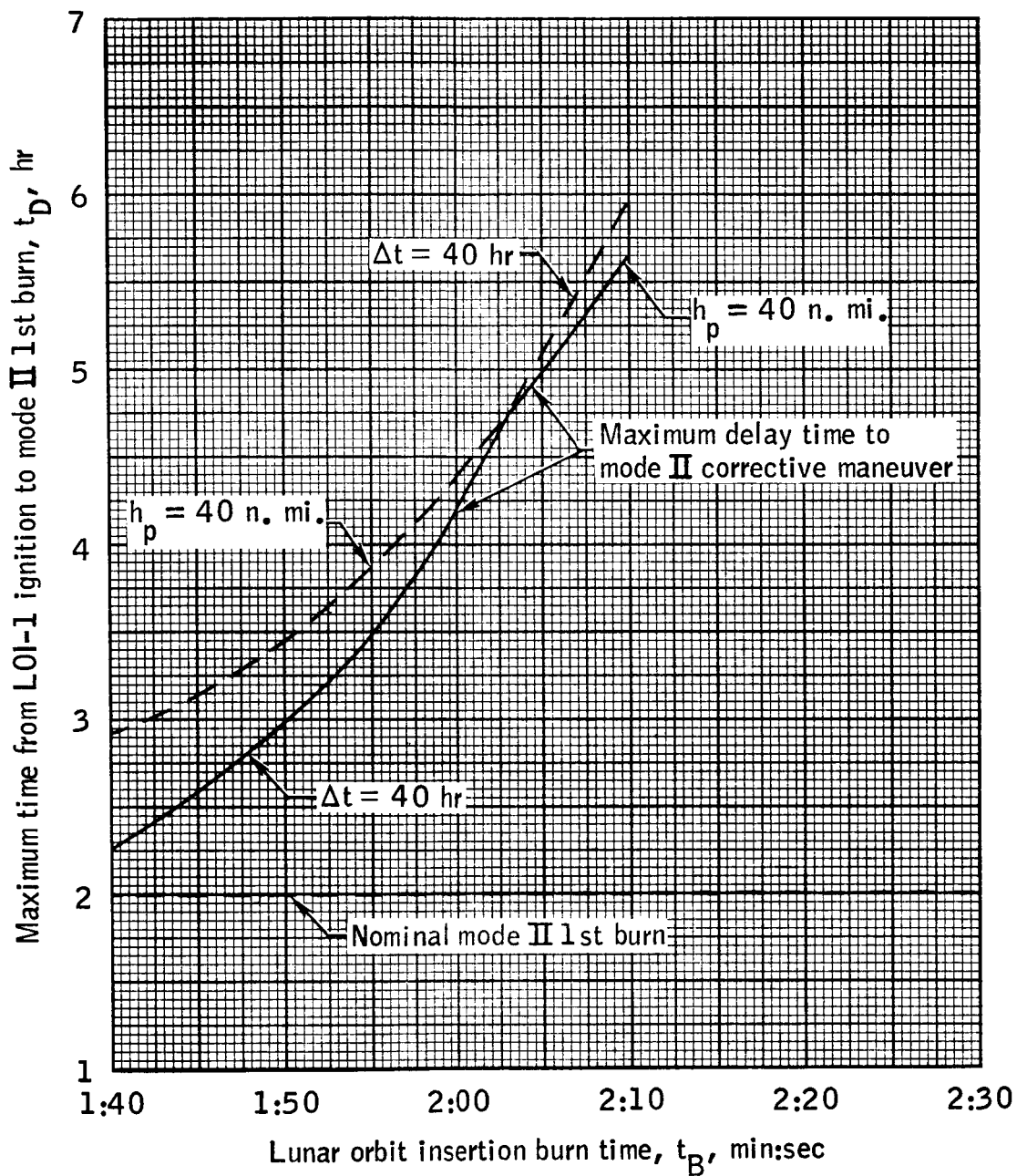


Figure 16.- Ground elapsed time of landing for FCUA mode I and II aborts (September 13, 1969).



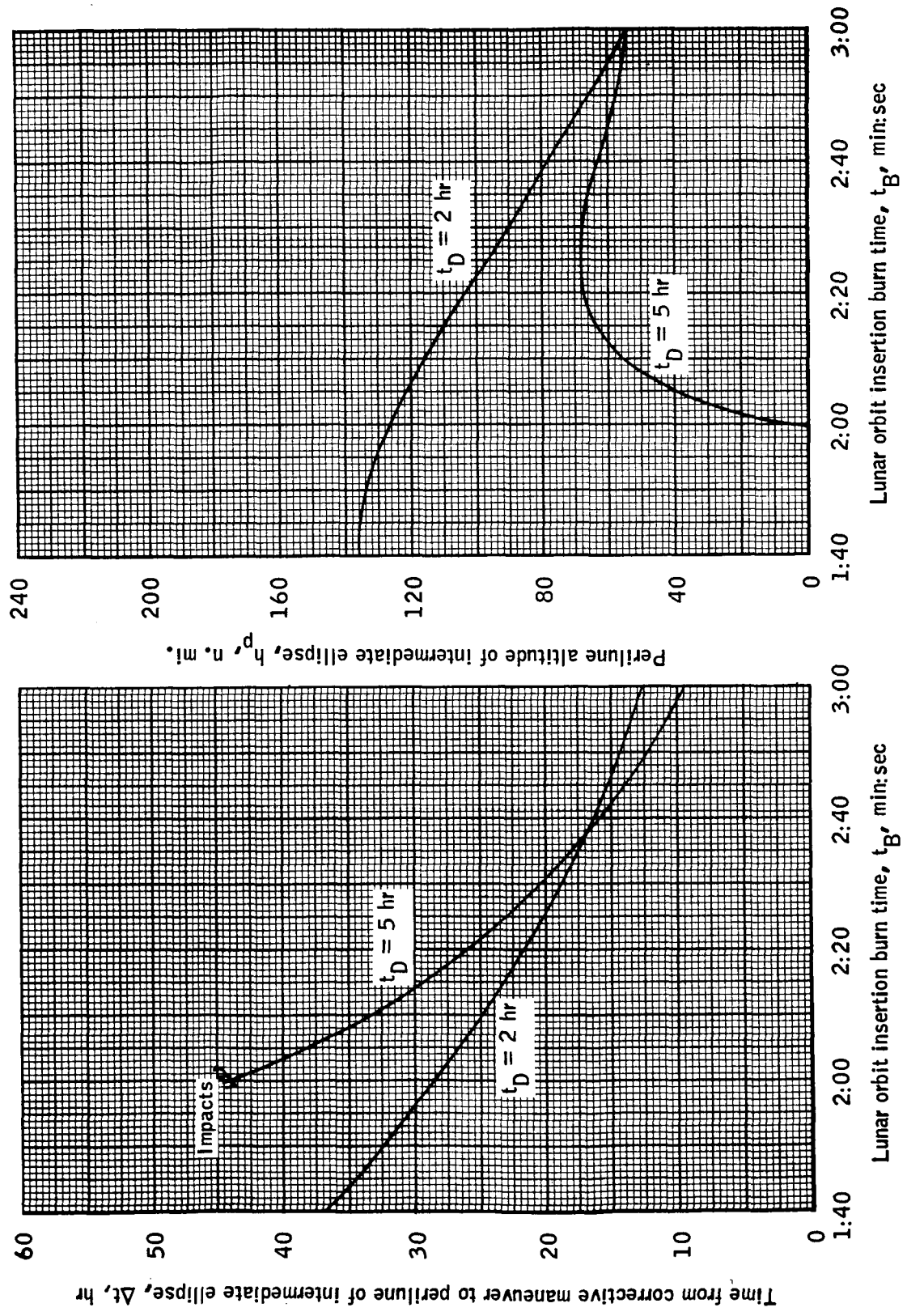
(a) First burn ΔV magnitude (corrective maneuver).

Figure 17.- Mode II abort analysis as a function of LOI burn time (September 13, 1969).



(b) Maximum allowable delay time to corrective maneuver ignition.

Figure 17.- Continued.



(c) Time from corrective maneuver to perilune of intermediate ellipse.

(d) Perilune altitude of intermediate ellipse.

Figure 17.- Concluded.

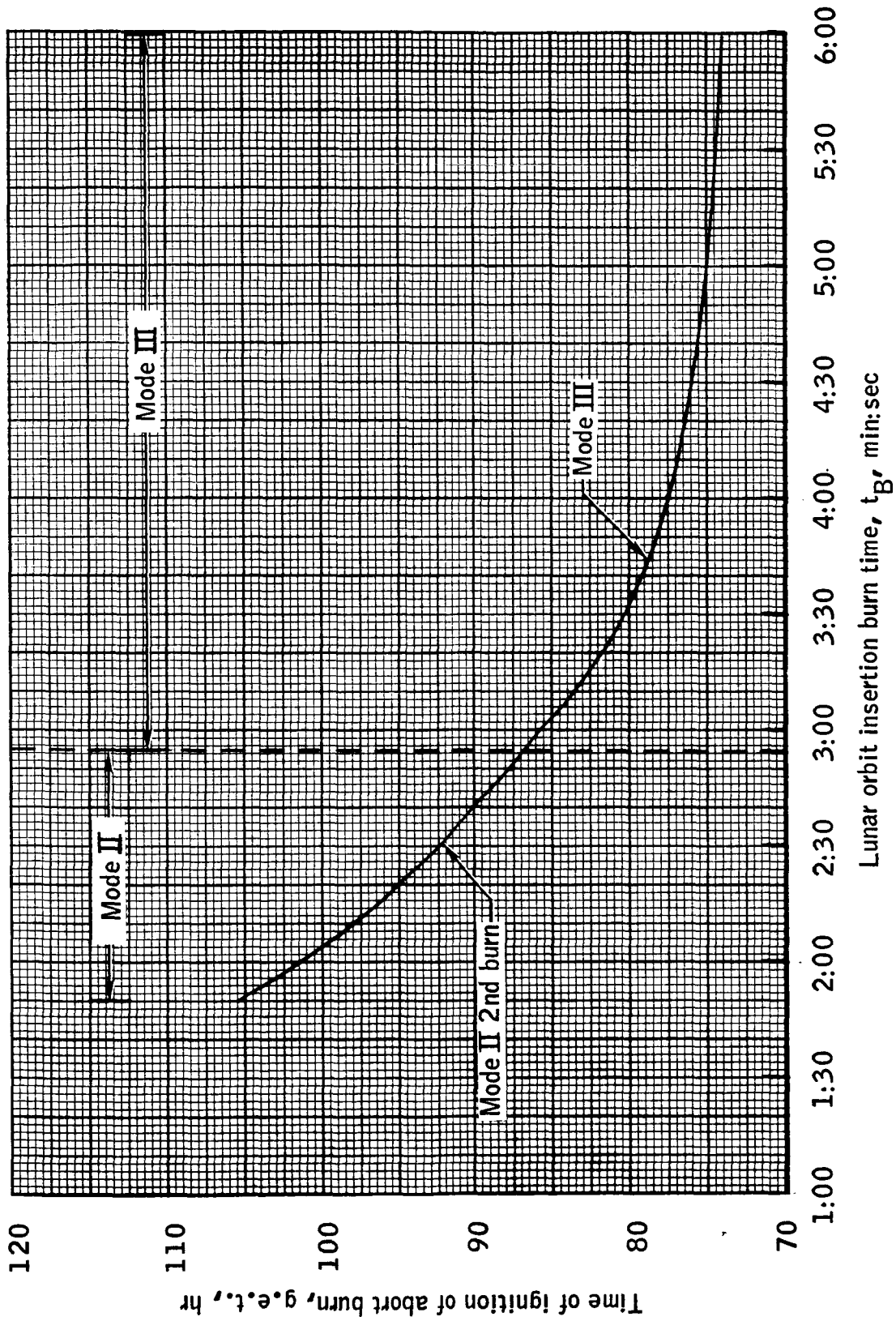


Figure 18. - Ground elapsed time of ignition of FCUA mode II second burn and mode III abort as a function of LOI burn time (September 13, 1969).

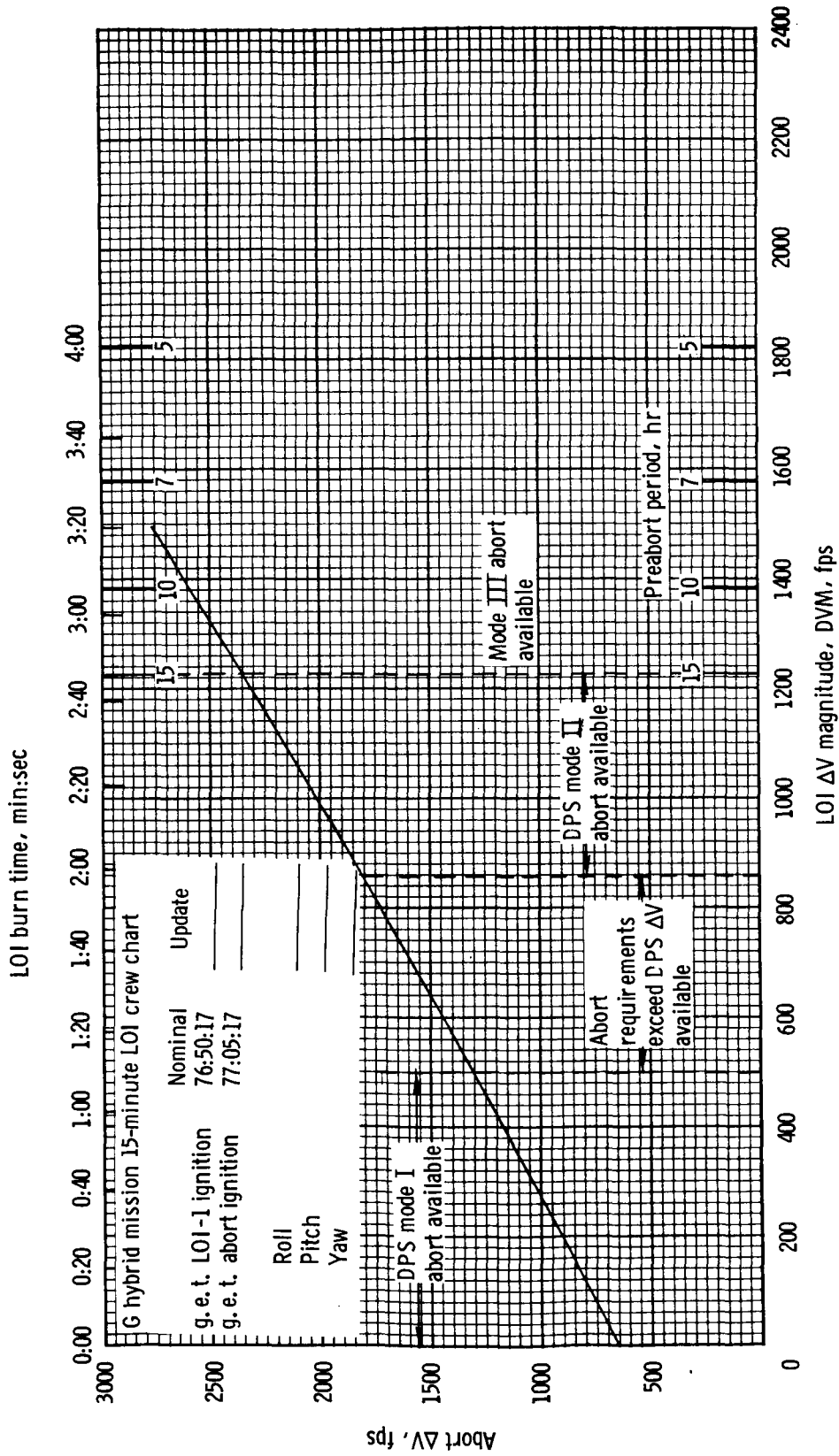


Figure 19. - LOI 15-minute crew chart for July 21, 1969, hybrid lunar mission.

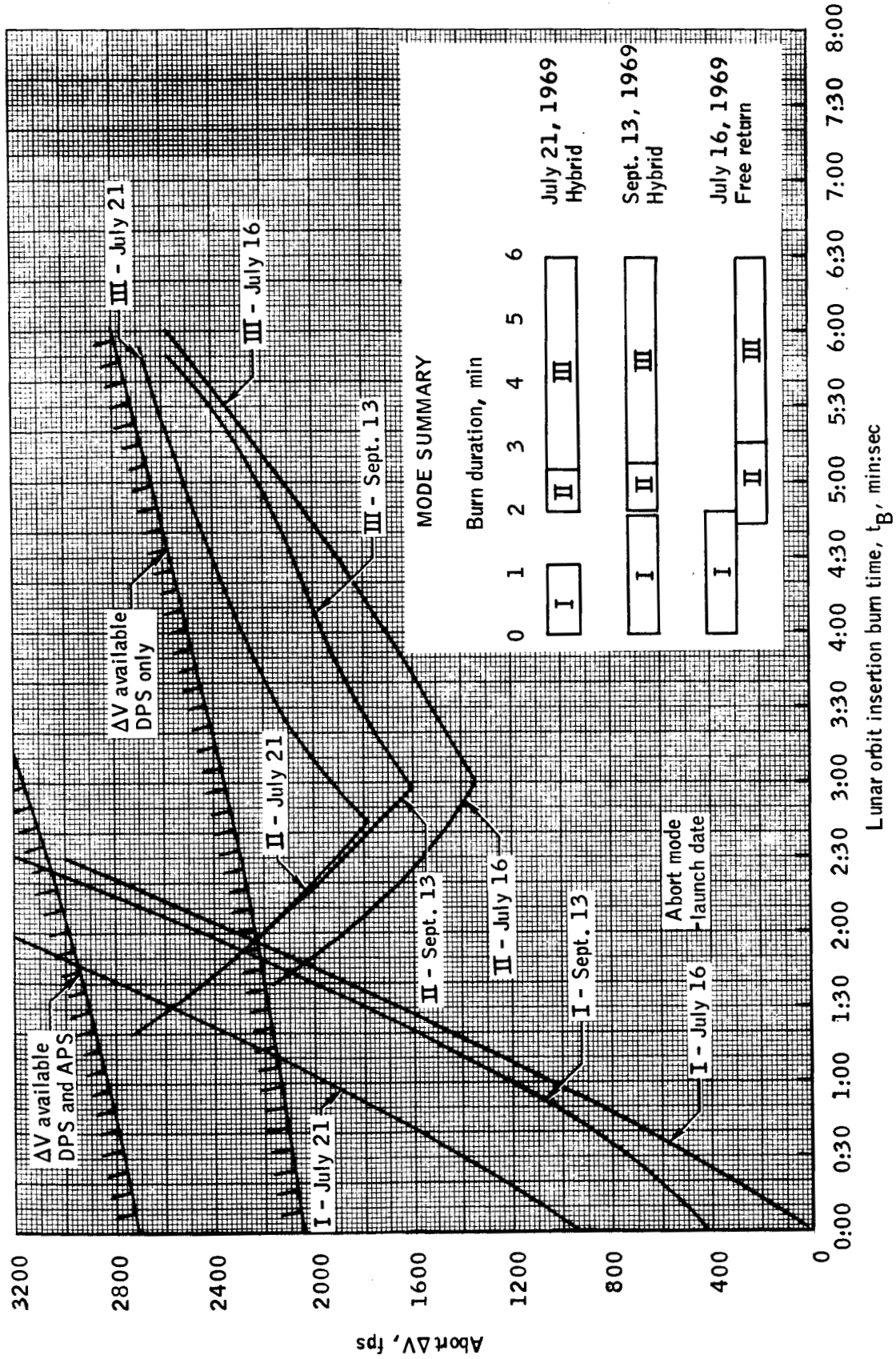


Figure 20.- Summary of LOI FCUA abort capability for typical hybrid and free-return missions.

APPENDIX A
MAJOR MISSION G MILESTONES FOR THE
CONTINGENCY ANALYSIS SECTION

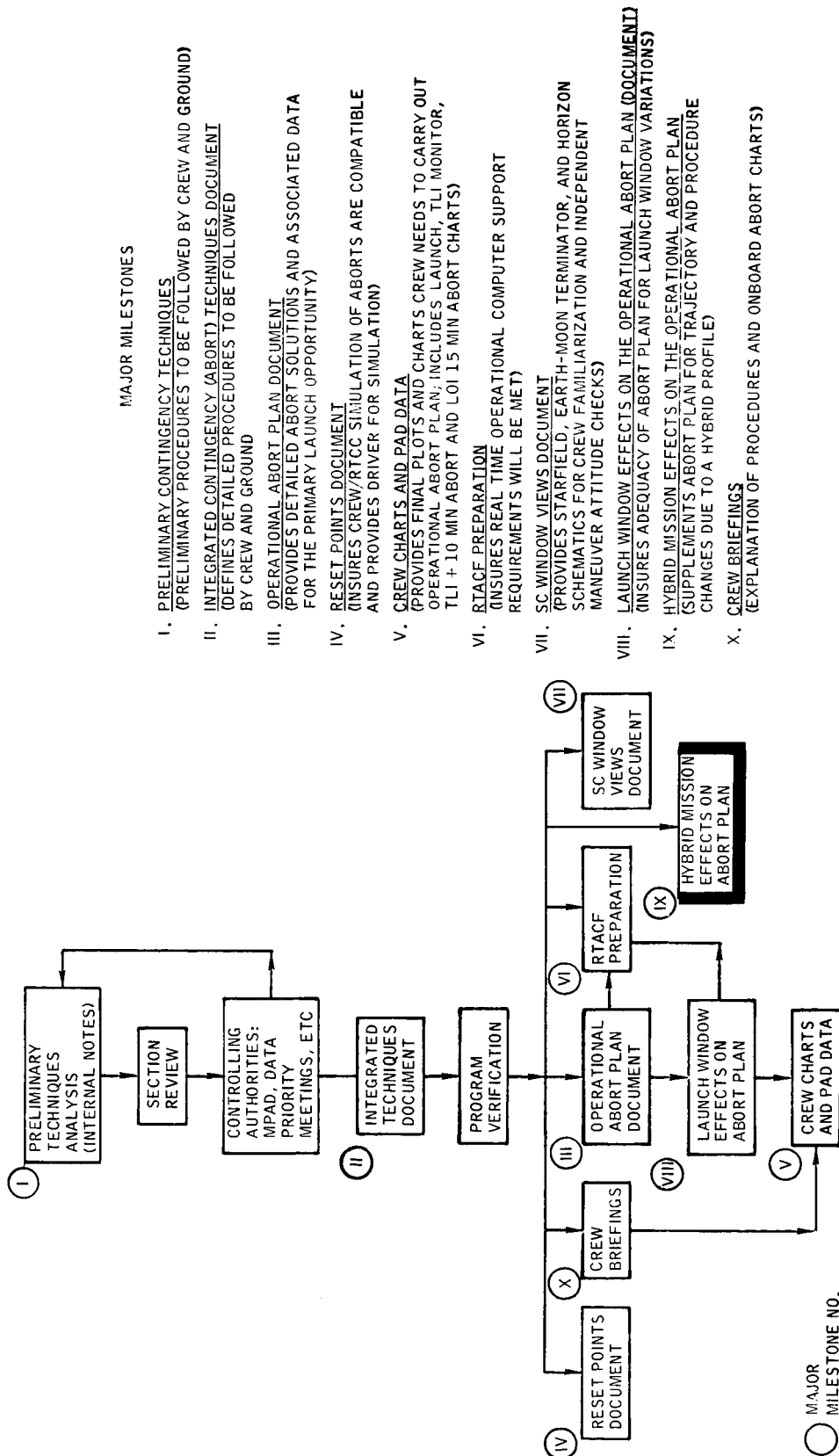


Figure A-1. - Major Apollo F and G milestones for the Contingency Analysis Section.

APPENDIX B

LOI ABORT CAPABILITY FOLLOWING SM JETTISON

(July 21, 1969, hybrid mission)

APPENDIX B

LOI ABORT CAPABILITY FOLLOWING SM JETTISON

(July 21, 1969, hybrid mission)

The region of the LOI burn in which a normal DPS backup to an SPS failure is not available was discussed in section 4.4. It was shown that use of the APS engine after a DPS burn and descent stage jettison can provide the necessary ΔV for the return-to-earth maneuver.

The only other procedure that can successfully return the spacecraft to earth involves jettison of the SM prior to the DPS burn. The primary constraint on this procedure is the transearth flight time following SM jettison because the LM would be required to provide the consumables normally provided by the SM. Therefore, the data presented in this section are limited to an analysis of the minimum transearth flight time possible for early LOI shutdowns in the critical region.

Previous analyses have indicated that such a procedure may be feasible if return times of 40 hours are possible after SM jettison. The time from DPS abort to landing for a July 21, 1969, mission (72° azimuth, first opportunity) is shown in figure B-1. It can be seen that for LOI shutdown prior to 1^m30^s , the TAZ decreases as the DPS abort is delayed. However, for later LOI shutdowns, the trajectory is such that the TAZ increases as the abort is delayed. In all cases, the abort $\Delta V = 4500$ fps which is approximately the DPS ΔV available following SM jettison.

Therefore, it is shown that a relatively short return time is possible when the SM jettison procedure is used. However, before the procedure is considered operationally feasible, an analysis of consumable problems and control problems associated with the DPS burn must be investigated.

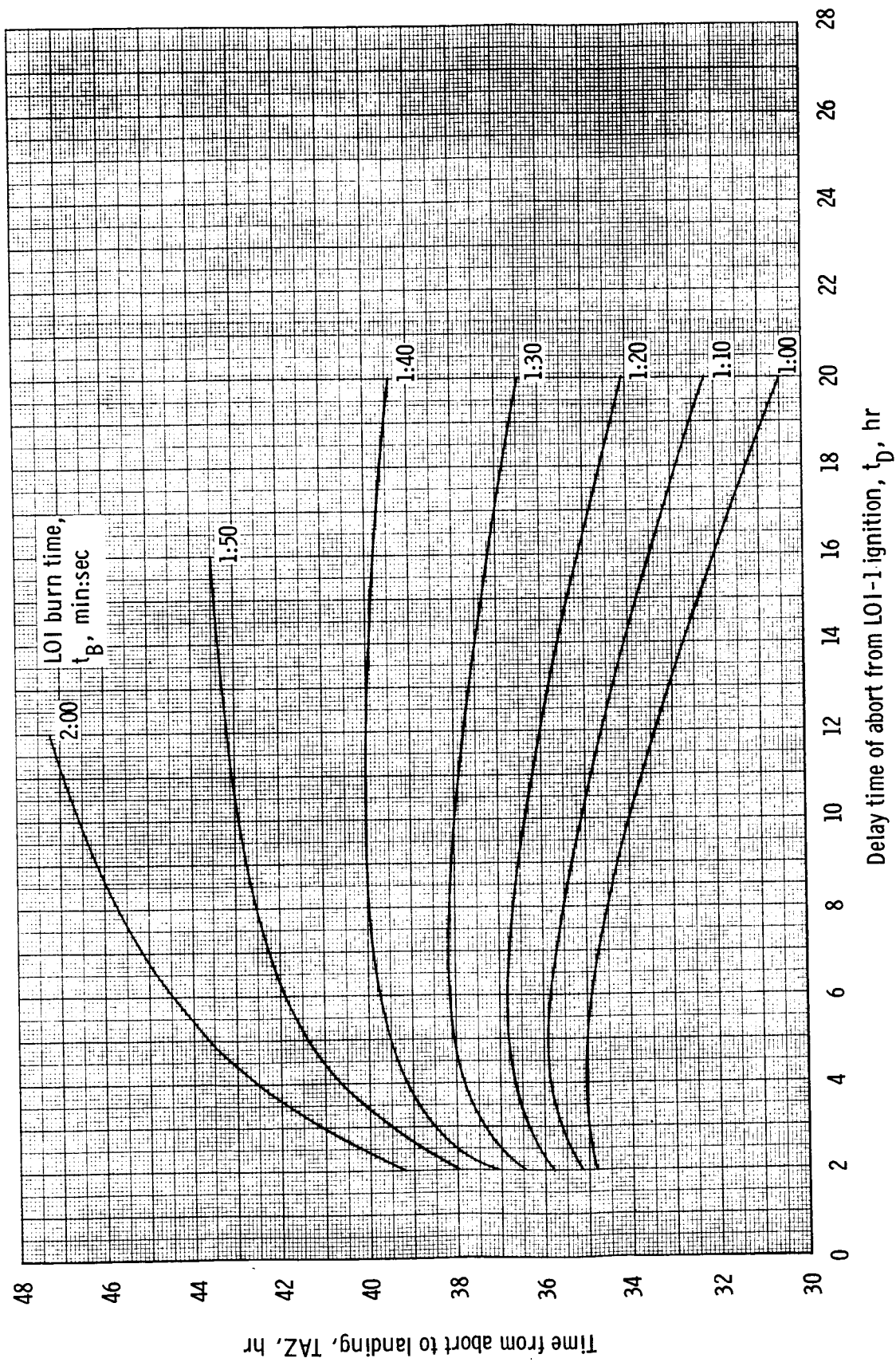


Figure B-1. - Time from DPS abort to landing following SM jettison for SPS failure during LOI, July 21, 1969
(72° azimuth, first opportunity).

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1. Contingency Analysis Section, Flight Analysis Branch: Operational Abort Plan for Apollo 11 (Mission G). MSC IN 69-FM-162, June 13 1969.
2. Contingency Analysis Section, Flight Analysis Branch: Launch Window Effects on the Apollo 11 (Mission G) Operational Abort Plan. MSC IN 69-FM-172, June 24, 1969.
3. Lunar Mission Analysis Branch: Return to Earth Requirements for Apollo Mission G Hybrid Trajectories. MSC memo 69-FM54-118, April 22, 1969.